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amber

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Model 3501

Distortion and Noise Measuring System

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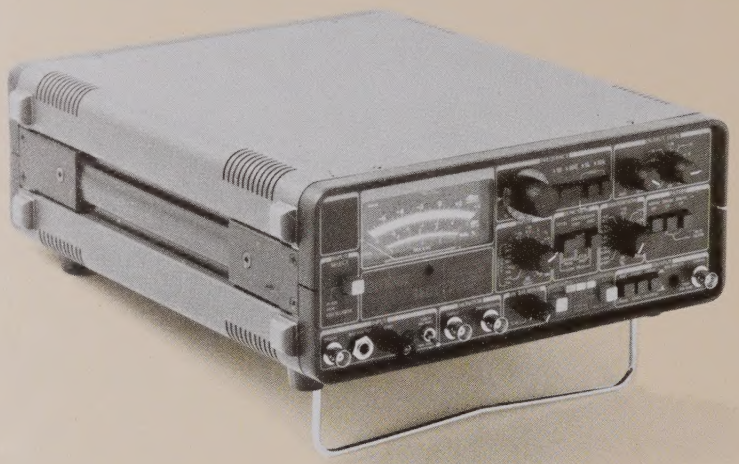
Distortion and Noise Measuring System



Super High Performance:	THD to below 0.0008%! Noise to below − 120 dBm (1 μV)
Easy to use:	Auto Null, Auto Set Level, Tracking Oscillator/Analyzer
Low Cost:	15% to 60% below competitive units
Portable:	Under ½ cu ft, 12.5 lbs — smaller than a portable oscilloscope
Additional Unique Features:	Frequency selective voltmeter for manual spectrum analysis, crosstalk measurements
Optional IMD:	Dual tone measurements to 100kHz as well as SMPTE, DIN, CCIF and IHF standards
Flexible Filtering:	Four user changeable filters for weighted noise measurements
Optional Balanced Input/output:	Output capability to over + 28dBm (+30dBm typical) into a 600 ohm load
Optional Rechargeable Battery:	For field use or ground loop problems
Optional Frequency Meter:	High resolution and fast update.
User Upgrade:	All options may be field installed.

The Amber 3501 is an ultra high performance distortion and noise measuring system. Distortion measurement capability is the best in the industry with measurements to below 0.0008% (−102dB)! The 3501 offers the convenience of automatic nulling and automatic set level in a portable low cost instrument. It provides several unique features for even greater measurement power such as manual spectrum analysis. Comprehensive filtering allows weighted noise measurements to virtually any standard — and the four filters are easily user changeable.

Configured to Your Application

A wide selection of field retrofitable options allows customization to specific user requirements. A powerful Intermodulation Distortion measurement capability allows measurements not only to various international standards but also front panel choice of frequencies from 2kHz up to 100kHz — a feature useful in qualifying TIM and other high frequency phenomena. Rechargeable battery systems are available for field use or floating applications in the lab.

Balanced Input and Output

For broadcast and professional audio applications a balancing option gives a balanced/differential input and a balanced/floating output with the highest output level in the industry — over +28dBm into a 600 ohm load (typically +30dBm). Front panel controls select the configuration: balanced or unbalanced, grounded or floating, terminated or unterminated.

Reliability

System reliability is enhanced by the liberal use of "cold switching" technology and high performance components such as precision conductive plastic controls, enclosed switches and gold contacts. RFI susceptibility is virtually eliminated by the linear front end.

Convenient and Portable

A well engineered front panel layout, automatic operation, comprehensive input/output configurations and full monitoring make the 3501 particularly easy to use and the convenient size and weight will be welcome by both the travelling technician and the crowded lab bench.

The Amber 3501 — highest performance and most features in a distortion measurement system but at the lowest cost.

Versatility. A wide variety of features allows the 3501 to be at home in any environment and gives the user fast and easy to achieve results.

For example, in testing high performance HiFi and Pro-Audio equipment, the 3501 has the state-of-the-art specs to give you the correct measurement results. The convenient dB relative control lets you make frequency response and signal-to-noise measurements directly and with a minimum of button pushing. The differential input lets you measure bridged power amplifiers and break ground loops.

In broadcast work the balanced input and output, 30kHz filter and RFI immunity allow fast proof of performance measurement to FCC recommendations.

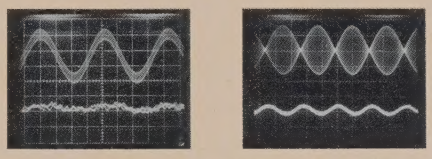
In transceiver testing, measurements by the SINAD method are easily handled with the auto-set-level feature and tracking oscillator. And the true rms detection gives a more accurate noise measurement. With special options, psophometric or C-message filters can be provided.

Comprehensive intermodulation distortion measurement capability.

IMD measurement capability lends a powerful qualifying technique to the 3501. In some situations, THD measurements are either difficult or yield results of questionable validity. Examples would be devices with significant band-width limitations such as tape recorders or telephone lines. Also those with high broadband noise such as encountered during acoustic measurements. IMD measurements are not limited by bandwidth — unlike THD the test frequency can be extended right out to the upper band edge of the device. And since the measurement technique is narrow band it is far less sensitive to noise.

Many other instruments don't offer IMD; those that do usually provide only the SMPTE measurement technique with fixed measurement frequencies of 60Hz and 7kHz. The 3501 can, of course, duplicate this now somewhat dated standard but also allows the user to set the HF component anywhere from 2kHz to 100kHz to properly qualify the high frequency performance of the device under test. Additionally, the 3501 can measure twin tone IMD to the CCIF and IHF recommendation. By connecting a simple (not necessarily low distortion) oscillator to a rear panel input, a dual tone composite signal is generated. This external oscillator and the 3501 internal oscillator may then be set to any pair of frequencies between 2kHz and 100kHz with a frequency difference of 10Hz to 1kHz. The 3501 will measure the difference frequency distortion component with the same operational ease as other IMD or THD measurements.

Distortion measurement techniques are becoming more sophisticated and extensive. Be prepared to qualify distortion to any of the new contemporary standards. The 3501 with the 006 option gives you that capability.



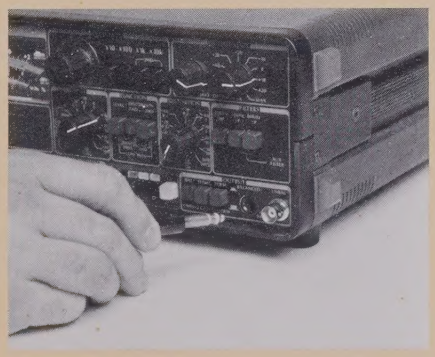
Typical IMD test signals and residual distortion waveforms. On the left is the SMPTE/DIN signal generated by the 3501 with option 006. On the right is the CCIF/IHF signal generated by using the 3501 and an external oscillator.

Balancing made easy.

Broadcast and Professional Audio applications usually require a balanced input and output facility in the measurement equipment to properly interface with the systems under test. The 3501 has a balanced input and a balanced output option to meet this requirement.

Input and output connectors are convenient jackfield style tip-ring-sleeve jacks (mating with PJ-051/WE-310 type plugs). This allows simple plug-in connection to systems. For component tests, adapters are provided to convert to banana jacks/binding posts.

The input/output configuration is easily set up with front panel controls. The input may be bridging (100k ohms) or terminating (600 ohms). The output may be left unterminated or terminated in 600 ohms. The output may also be completely floated from chassis or the center tap may be referenced to ground for true longitudinal balance. And the high power (+ 30dBm typical maximum) output lets you check headroom in the highest level systems.

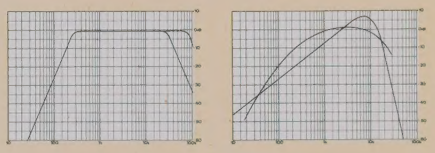


Balanced input/output connectors and switching.

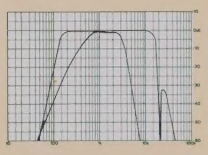
Comprehensive filtering for all situations.

Every measurement application has its own set of special requirements. One area that experiences a wide variation is noise measurement. Numerous international standards define particular frequency weighting curves. With the diversification of industries requiring distortion and noise measurement; Broadcast, Audio, HiFi, Communication, Industrial, there is a need for versatility to be able to easily serve this requirement. The Amber 3501 has four front panel selectable filter positions and each of the four positions can accept a plug-in filter from a wide library of standard and custom versions, including for example ANSI/IEC "A" weighting and CCIR, CCITT.

Simple one, two or three pole networks can be achieved with passive modules since the host instrument contains active circuitry to support these. More complex networks can be handled by a variety of modules from Amber with complexities of 7 to 20 poles. Universal filter cards allow construction of special filters.



Standard **Optional**



Custom

Standard high pass and low pass filters supplied with the 3501. Optional filters shown are ANSI/IEC weighting and CCIR 468-2. Custom filters include C message weighting and IHF band pass with 19kHz notch illustrated.

Convenience of use.

The ergonomics of the panel and system operation was a prime consideration in the design of the 3501. Neat functional groupings of controls simplify front panel understanding. Simple pushbutton setup of measurement modes greatly speeds up operation; you can rapidly switch between LEVEL, TOTAL HARMONIC DISTORTION and INTERMODULATION DISTORTION with just three simple buttons, no "set level" knobs to twiddle, no adjustment, no setup calibration. Automatic servos handle the internal housekeeping and give you fast, accurate results.

A one button "self check" function lets you quickly verify output level and instrument performance.

Fast acting warning lights tell you if some front panel control is set wrong. With the lights extinguished and an on-scale meter reading, you have the confidence the result is both valid and accurate.

Model 3501
Distortion and Noise Measuring System

True rms meter with convenient linear dB scales for constant measurement resolution.

Smooth 6 to 1 vernier drive for simultaneous oscillator and analyzer tuning and manual frequency sweeps.

Fast LED indicators indicate the signal is outside capture range of automatic set level and automatic null servos.

Single push button lets you check generator output level delivered to load, verify instrument performance, etc.

Differential input for balanced output devices or push-pull/ bridged power amplifiers or to break ground loop.

Monitor outputs to view input and distortion components on external oscilloscope or spectrum analyzer.

dB relative control simplifies S/N and frequency response measurement. Allows meter to be offset ± 12 dB.

Fast push button selection of instrument function. No need to go through set up or adjustment procedure when changing modes. Optional IMD function to SMPTE, DIN, CCIF and IHF standards.

Calibrated output attenuator presents constant output impedance. Output amplifier can deliver + 30 dBm (typical) in Balanced mode. OFF position for fast S/N readings.

Four filters for comprehensive noise measurement. HP and LP filters for hum and noise rejection are 18 dB/octave. AUX filter may be ANSI/IEC "A" weighting, CCIR or others. All filters user changeable.

Actual Size

Convenient connectors for balanced or unbalanced connection to device under test. Leveled generator is flat to ± 0.1 dB over audio range.

DISTORTION control doubles as RATIO control for signal to noise measurements down to − 100 dB full scale.

BAND PASS mode for manual spectrum analysis. LOW PASS mode for selectable bandwidth S/N ratio measurements.

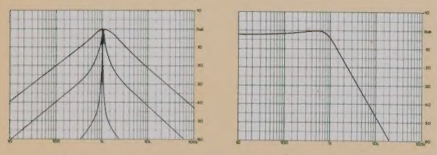
Battery test button checks charge level of battery on meter. Charge LED indicates high charge rate. EXTERNAL POWER PRESENT verifies AC mains source.

Simple push button selection of output configuration. GROUND/FLOAT button lets you break ground loop.

A broad complement of input/output connectors and pushbutton selected configurations allow fast interface to virtually any measurement situation. No need to look for an external balancing adapter or experiment with a rat's nest of banana plugs to sort out a ground loop.

Unique features. The 3501 includes, as standard equipment, a number of powerful and unique measurement facilities. Two of the most useful are the two narrow band level measurement functions. One of these allows you to configure the instrument as a selective voltmeter with a sensitivity down to below −120dBm. In this mode, a tunable band pass filter is inserted in the measurement path and the full meter amplification is available. The filter tracks the oscillator for convenient crosstalk measurements from 10Hz to 100kHz. The bandwidth is approximately one third octave (12%) but can be internally changed to values between one octave and sharper than one-tenth octave. This feature lets you do manual spectrum analysis of noise, sort out distortion components from another analyzer or look for signals in noise.

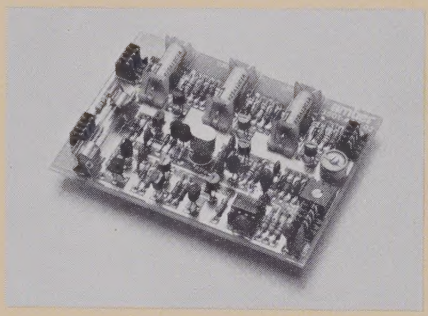
The second narrow band mode is the low pass function. This allows you to set up the instrument as a selectable bandwidth, high sensitivity noise meter. The upper measurement cutoff frequency may be set using the front panel FREQUENCY control over the full range of 10Hz to 100kHz. For example, a common use might be to specify a 20kHz audio bandwidth. Signal-to-noise measurements are very easy; simply set the signal reference in the LEVEL mode, set a 0dB reference with the dB relative control, choose the measurement bandwidth (20kHz, for example) and select the LOW PASS function. The signal-to-noise ratio can be read directly in dB with a 0 to 110dB range (using the DISTORTION control as the meter sensitivity adjustment). To qualify this noise with a particular weighting characteristic (ANSI/IEC "A" or CCIR, for example) just push the AUX FILTER button if that filter is installed.



Tunable filters included as standard. On the left is the response of the BAND PASS mode showing various band widths available: 100%, 12% (standard) and 1%. On the right is the LOW PASS mode response. Both curves are normalized to 1kHz but front panel tunable from 10Hz to 100kHz.

Lower noise. The 3501 uses a high performance FET cascode front end to prevent several potential problems. The preamplifiers of most traditional analyzers use an integrated circuit which exhibits a non-linear input capacitance. This can cause two problems: distortion will increase when the source impedance of the device under test is high (or fed via a high resistance) and rectification can occur with very high frequency signals thereby causing RFI problems. The Amber preamp is linear into the Megahertz region so high source impedance does not introduce distortion. Thus the 100k ohm input attenuator does not present a problem and susceptibility to RF interference is virtually eliminated due to the linearity of the input. (Note that conventional input filtering, ferrite beads, LC networks, etc are often ineffective due to the common mode nature of RFI and poor ground impedance at high frequencies.)

A side benefit of this FET front end is a lower 1/F noise (or flicker noise), an advantage when measuring devices with low end boost such as phono preamps.

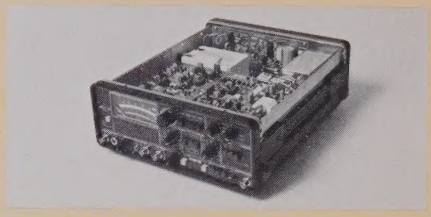


Cascode FET preamplifier.

Intelligent power supply. The 3501 incorporates a sophisticated power supply to power the instrument either from external mains voltage or optional internal rechargeable battery. Switch over between the two power sources is automatic — the external supply takes priority until it falls below a preset level at which time the instrument automatically and quietly switches over to the internal battery. A front panel EXTERNAL POWER PRESENT indicator shows when external power of a sufficient magnitude is available (even with the 3501 switched off). A low battery warning indicator shows when the instrument has exhausted 90% of the battery by flashing the POWER ON indicator. The duty cycle of the flash decreases until the instrument is automatically switched off at the end of battery life to prevent damage to the battery by deep discharge.

The built-in charger is a two rate system. The front panel CHARGE indicator shows the high rate that is set initially. After the battery has reached approximately 90% of charge, the charger automatically reverts to a float mode and extinguishes the CHARGE indicator.

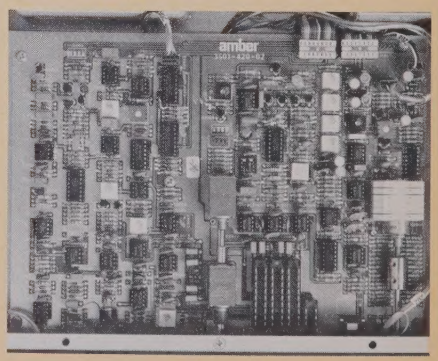
An optional international AC mains adapter allows the instrument to operate from virtually any international source from 100V to 240V at 50 to 60Hz. An IEC mains receptacle and interchangeable American or European fuse holder allows convenient use anywhere.



Service access is fast and convenient. Power supply is at the rear.

Reliability. A distortion measurement system puts heavy demands on components, switches and controls. That is why we researched virtually every component for reliability and life. We found most conventional switches to be the cause for many instrument failures so we replaced them with something better — electronic switching in most areas, conductive plastic controls and enclosed gold contact switches elsewhere. We have eliminated 80% of the mechanical contacts and replaced the remaining 20% with the best available. (For example, the FREQUENCY control is a conductive plastic potentiometer with a typical lifetime of up to one million operations — other instruments use several banks of switches, and switches usually have a lifetime of perhaps 10,000 to 25,000 operations.) In the 3501, the FUNCTION switching and most of the gain switching is done by CMOS circuits which simply **never** wear out.

Access is fast and easy for calibration or if you do have to service a 3501. Circuit boards are plug-in and can be removed with just a screwdriver. All integrated circuits are socketed, all parts standard off-the-shelf.



Part of the precision oscillator and notch filter showing the conductive plastic controls and enclosed switches.

Model 3501
Specifications

SIGNAL SOURCE (unbalanced output)

Frequency Range: 10Hz to 100kHz in four overlapping ranges. Continuously variable vernier drive FREQUENCY control permits selection of any frequency.

Output Level Range: maximum +18dBm (+20 dBm typical) into 600 ohm load, (12.6V rms open circuit) to <60 dBm minimum plus OFF. 9 steps of 10 dB (±0.5 dB at 1kHz) and variable control of >10dB.

Amplitude Flatness: (referred to 1 kHz) ±0.1 dB 20 Hz to 20 kHz; ±0.2 dB 10 Hz to 100 kHz

Output Source Impedance: 600 ohms ± 2% at all control settings (except MAX where impedance is approx. 300 ohms).

Distortion: (THD) ($R_L \geq$ 600 ohms): 50 Hz to 5 kHz ≤0.0008% (−102 dB); 10 Hz to 10 kHz ≤0.0015% (−96 dB); 10 kHz to 50 kHz ≤0.003% (−90 dB); 50 kHz to 100 kHz ≤0.006% (−84 dB)

Additional specifications for option 006 IMD:

Signal Source (SMPTE/DIN Mode): Composite mix of main oscillator and additional low frequency oscillator. LF Signal: 60 Hz ±5% (internally changeable from 20 Hz to 500 Hz) HF Signal: 10 Hz to 100 kHz set by front panel FREQUENCY control.

Amplitude Ratio: LF:HF 4:1 ±5% (±0.5 dB)

Residual IM (SMPTE/DIN Mode): ≤0.003% (−90 dB)

Additional specifications for option 005 Balanced Output:

Output Level Range: Maximum +28 dBm (+30 dBm typical) into 600 ohm load, (24V rms open circuit) to ≤−60 dBm minimum plus OFF

Amplitude Flatness: (referred to 1 kHz) ±0.2 dB 20 Hz to 20 kHz; ±0.5 dB 10 Hz to 100 kHz

Output Source Impedance: 600 ohms ±2% at all control settings except MAX where impedance is <100 ohms

Distortion (THD) (+28 dBm to −30 dBm) terminated or unterminated: 50 Hz to 5 kHz ≤0.0015% (−96 dB); 20 Hz to 20 kHz ≤0.003% (−90 dB); 20 kHz to 50 kHz ≤0.006% (−84 dB); 50 kHz to 100 kHz ≤0.01% (−80 dB); 10 Hz typically ≤0.03% (−70 dB)

DISTORTION MEASUREMENT (THD + N) (specifications apply to both balanced and unbalanced input except where noted):

Fundamental Frequency Range: 10 Hz to 100 kHz in four overlapping ranges

Input Level Range: +40 dBV to −30 dBV (+42 dBm to −28 dBm/100 V to 30 mV rms)

Measurement Bandwidth: 10 Hz to ≥300 kHz ±3 dB

Accuracy: (harmonic measurement) Fundamental 20 Hz to 20 kHz: ±1 dB; Fundamental 10 Hz to 50 kHz: ±2 dB; Fundamental 50 kHz to 100 kHz: ±3 dB

Residual THD + N: (Input signal within top third of meter scale in LEVEL mode and signal >0dBV/1 Vrms) 50Hz to 5kHz, 30kHz BW: ≤0.0008% (−102dB); 10Hz to 10kHz, 80kHz BW: ≤0.0015% (−96dB); 10kHz to 50kHz, full BW: ≤0.003% (−90dB); 50kHz to 100kHz, full BW: ≤0.006% (−84dB)

Supplemental Data for THD + N Measurement:

Fundamental Rejection: Typically 10dB below specified residual THD of instrument or actual signal THD, whichever is greater.

DISTORTION MEASUREMENT IMD (requires option 006. Specifications apply to both balanced and unbalanced input except where noted.):

Function:

SMPTE/DIN MODE: Measures AM modulation of HF signal by LF signal as a percentage or ratio of HF signal

CCIF Mode: Measures difference frequency component ($F_1 - F_2$) expressed as a percentage or ratio of high frequency twin-tone composite signal

Frequency Range: SMPTE/DIN: Low frequency: 10Hz to 500Hz; High frequency: 2kHz to 100kHz

CCIF: Mean frequency: 2kHz to 100kHz; $F_1 - F_2$: 10Hz to 1kHz

Input Level Range: Same as THD

Amplitude Mix: SMPTE/DIN: 1:1 to 5:1 (LF:HF)

CCIF: 1:1 ±10%

Residual Distortion/Accuracy: SMPTE/DIN (LF 20Hz to 200Hz, HF 5kHz to 20kHz, mixed at 4:1): ≤0.003% (−90dB)/±1dB (±10%)

CCIF (5kHz to 20kHz, $F_1 - F_2$ = 20Hz to 500Hz mixed at 1:1: ≤0.003% (−90dB)/±1dB (±10%)

LEVEL/NOISE MEASUREMENT FUNCTION (specifications apply to both balanced and unbalanced input except where noted):

Input level range: +40dBV, (+42dBm, 100V rms) maximum to −70dBV (−68dBm, 0.3mV) in LEVEL mode and −130dBV, (−128dBm, 0.3μV) in Low Pass or Band Pass mode

Bandwidth (−3dB): 3Hz to ≥300kHz

Residual Noise (source resistance ≤1k ohm):

Low Pass Mode: F_c ≤5kHz: ≤−120dBV (1μV); F_c ≤100kHz: ≤−110dBV (3μV)

Band Pass Mode (12% BW): F_c ≤1kHz: ≤−120dBV (1μV); F_c ≤100kHz: ≤−100dBV (10μV)

Accuracy, LEVEL Mode: 20Hz to 20kHz: ±2% of range (±0.3dB)
Input Signals −60dBV (1mV) or greater: 10Hz to 100kHz: ±4% of range (±0.5dB)

Common Characteristics, measurement section.

Input Impedance: 100k ohms ±2% shunted by ≤100pf (100k ohms ±2% each side to ground shunted by ≤200pf balanced)

Common Mode Rejection: ≥40dB at 50 or 60Hz

Supplemental data for measurement section:

Meter Detection: True rms for signals with crest factor ≤3

Meter Scales: dBm (ref 1mW, 600 ohms), dBV (ref 1V rms) Volts, percent

FILTERS (useable on all functions):

400Hz High Pass (standard): −3dB at 400Hz ±5%, at least 40dB rejection at 60Hz (18dB per octave)

30kHz Low Pass (standard): −3dB at 30kHz ±5% (18dB per octave)

80kHz Low Pass (standard): −3dB at 80kHz ±5% (18dB per octave)

Supplementary Data for Filters:

Auxiliary Filter: 16 PIN socket to accept various filters available from Amber including ANSI/IEC. A Weighting, CCIR and others.

Band Pass Level Mode: Tuneable band pass filter with a bandwidth of approximately 12%. User changeable from 100% to less than 1% with single resistor change.

Low Pass Level Mode: Low pass filter with tuneable cutoff point. Slope characteristics: 12dB per octave. Pass band ripple ≤3dB.

General:

Temperature, operating: 0°C to +50°C; storage: −40°C to +75°C

Humidity Range: <95% RH, 0°C to +40°C

Power Requirements: 120V rms +5%, −10%, 50/60Hz. Option 003 100, 120, 220 or 240V rms +5%, −10%, 48 to 62Hz. Instrument may also be powered from an external source of DC nominal 12.5V to 18V at <2A or 14V AC, 40VA.

Internal Battery: 12V rechargeable battery and charging system provides
(option 001) 1.5 hours or more of instrument operation after full charge.
(option 002): Same as above but provides 3 hours or more.

Dimensions (excluding bottom feet and front and rear panel projections):
H x W x D: 114 mm x 292 mm x 356 mm (4.5 in x 11.5 in x 14 in)
Weight: Basic instrument: 5.7 kg (12.5 lbs)
As above with 001 Battery: 6.8 kg (15 lbs)
As above with 002 Battery: 8.2 kg (18 lbs)

Note: Values shown in SPECIFICATIONS are warranted specifications. SUPPLEMENTARY DATA shown in italics are non-warranted data supplied for information only.

All specifications subject to change without notice.

Options and Accessories

001 Rechargeable battery & charger system. 12V 2.5AH battery and power supply provides independent instrument power and isolates grounds. Gives approximately one and one half hours or more of operation on a full charge. Automatically shuts down instrument when battery reaches end of life.

002 Extended life battery & charger. Same as 001 above but with 12V 5AH battery for approximately 3 hours or more of operation.

003 International AC adapter/charger. Replaces 120V AC transformer normally supplied with one suitable for use on 100, 120, 220, 240V AC +5%, −10% 48 to 62Hz. Contains IEC standard mains receptacle, voltage tap selector and US/European type fuse holder. Housed in metal box and supplied with mating mains cable with European color code suitable for user terminated AC mains plug.

004 Balanced input. Adds a differential input preamplifier to provide active balanced input for use in professional/ broadcast systems and for measurement of non-ground referenced sources. Also useful to break ground loops.

005 Balanced output. Adds a floating/ balanced output to instrument and increases capability to provide up to +28dBm (+30dBm typical) into a 600 ohm load. Uses a transformer for true float and a proprietary active correction technique (Patent pending) to virtually eliminate distortion contribution.

006 Intermodulation distortion measurement/Generation facility. Adds a second (low frequency) oscillator and mixing circuitry to provide twin-tone composite signal (SMPTE type) and intermodulation measurement circuits to measure SMPTE, DIN, CCIF or IHF distortion. Frequency range 2kHz to 100kHz.

358 High resolution frequency meter. Adds a six digit frequency readout of internal oscillator or external signals. Frequency multiplier provides two orders of magnitude improvement in measurement speed/resolution over conventional meters with several readings per second and up to 0.01Hz resolution. "Smart" signal detector automatically blanks display in absence of sufficient signal amplitude. Auto range circuitry (with manual override) permits measurement from below 10Hz to over 500kHz (typically 1MHz). Using the high meter sensitivity and filtering of the 3501, valid measurement of low level and noisy signals is possible. Pushbutton input selection permits measurement of 3501 oscillator, external signal input or the external signal with filtering.

Pushbuttons select either fast (approx. 3 readings/second, 0.1Hz resolution) or high resolution (0.01Hz resolution, 1 reading/second).

The 358 is powered by the 3501 internal power supply and automatically switches off when the 3501 is turned off. It mounts on the top cover of the 3501 adding approximately 1.2 inches (3 cm) to the height and is 7.7 inches (20 cm)

wide by 8.5 inches (22 cm) deep. It plugs in to existing connectors on the 3501 and may be field retrofitted.

Filters. To accommodate various noise weighting standards several special and custom filters are available. Normally, if a single optional filter is ordered, it will be fitted to the AUX FILTER position of the 3501. Alternatively, any of the four filter positions may be populated with any of several available filters.

Typical choices for standard optional filters include ANSI/IEC "A" weighting and CCIR 468-2.

Custom filters include the IHF-T-200/IEEE 185 receiver band pass, the telecommunications C-message weighting with and without notch, program weighting and Psophometric.

One, two and three pole high pass and low pass filters are easily accommodated and may be either purchased from Amber or constructed by the user from data supplied in the 3501 owner's manual.

Ordering Instructions

3	5	0	1	—	0	0	0	0	0

POWER OPTION	INTERFACE	MEASUREMENT	AUXILIARY FEATURES	AUXILIARY FILTER
0 120 VAC	0 UNBALANCED	0 THD only	0 NONE	0 NONE
1 120 VAC +001 BATTERY	1 BALANCED IN 004	1 IMD 006	1 358 FREQ COUNTER	1 ANSI "A"
2 120 VAC +002 BATTERY	2 BALANCED OUT 005	2	2	2 CCIR
3 100/120/220/ 240V AC 003	3 BAL IN/OUT 004 + 005	3	3	3 IHF/IEEE Band Pass
4 100/120/ 220/240V AC 003 + 001 BATT	4	4	4	4 Psophometric
5 100/120 220/240V AC 003 + 002 BATT	5	5	5	5 C Message

Example: a basic 3501 with no options is a 3501-00000. A 3501 with the 001 battery option, 004 balanced input, 005 balanced output, 006 IMD and an ANSI/IEC "A" weighting filter in the AUX FILTER position would be a 3501-13101.

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AMBER MODEL 3501

DISTORTION and NOISE

MEASURING SET

Issue 02

August 1982

OWNER'S MANUAL

AMBER MODEL 3501 OWNER'S MANUAL

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Other patents pending.

OWNER'S MANUAL

OPERATING and SERVICE MANUAL

Issue 02 August 1982

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SECTION 1

GENERAL INFORMATION

1. GENERAL INFORMATION

1.1 Instrument Description

The Amber model 3501 Distortion and Noise Measuring Set incorporates in a single compact enclosure an ultra low distortion sine wave generator, a high performance total harmonic distortion measuring system and a wide range, high sensitivity signal level and noise measuring facility.

In addition, a tunable band pass filter is included allowing the system to function as a selective voltmeter for manual spectrum analysis. This filter may also be configured as a low pass filter for band limited noise measurements.

The instrument incorporates a comprehensive set of user modifiable filters for noise measurements to various standards and band limiting in the distortion mode.

As an option, the instrument may also be fitted with an additional oscillator and an Intermodulation Distortion measurement facility.

The instrument contains a high efficiency power supply and may optionally include an internal rechargeable battery and charger. It may be powered from North American standard 115V AC mains or, with an option, may be powered from international voltages from 100V to 240V AC.

The model 3501 provides a high level of performance in a size significantly smaller than conventional instruments yet its performance in virtually every parameter rivals that of the best laboratory instruments. Speed of operation and speed of measurement have been optimized and automatic operation is provided for many functions.

MODEL 3501 SPECIFICATIONS

SIGNAL SOURCE (unbalanced output)	
Frequency Range	: 10Hz to 100kHz in four overlapping ranges. Continuously variable vernier drive FREQUENCY control permits selection of any frequency.
Output Level Range	: maximum +18dBm (+20dBm typical) into 600 ohm load, (12.6V rms open circuit) to ≤60dBm minimum plus OFF.
Output Level Control	: 9 steps of 10dB (±0.5dB at 1kHz) and variable control of ≥10dB.
Amplitude Flatness (referred to 1kHz)	: ±0.1dB 20Hz to 20kHz ±0.2dB 10Hz to 100kHz
Output Source Impedance	: 600 ohms ±2% at all control settings (except MAX where impedance is approx. 300 ohms).
Distortion : (THD) (RL ≥ 600 ohms)	: 50Hz to 5kHz ≤0.0008% (-102dB) 10Hz to 10kHz ≤0.0015% (-96dB) 10kHz to 50kHz ≤0.003% (-90dB) 50kHz to 100kHz ≤0.006% (-84dB)

Additional specifications for option 006 IMD:	
Signal Source (SMPTE/DIN Mode)	: Composite mix of main oscillator and additional low frequency oscillator.
Amplitude Ratio	: LF:HF 4:1 ±5% (±0.5dB)
LF Signal	: 60Hz ±5% (internally changeable from 20Hz to 500Hz)
HF Signal	: 10Hz to 100kHz total range.
Residual IM (SMPTE/DIN mode)	: ≤0.003% (-90dB)

Supplementary data for option 006:

CCIF Mode	: *Rear panel external input for second signal to mix with internal oscillator to generate twin-tone composite signal. With external oscillator level of approximate +10dBV (316mV rms) mix will be 1:1.*

Additional specifications for option 005 Balanced Output:

Output Level Range	: maximum +28dBm (+30dBm typical) into 600 ohm load, (24V rms open circuit) to ≤-60dBm minimum plus OFF
Amplitude Flatness (referred to 1kHz)	: ±0.2dB 20Hz to 20kHz ±0.5dB 10Hz to 100kHz
Output Source Impedance	: 600 ohms ±2% at all control settings except MAX where impedance is <100 ohms
Distortion (THD) (+28dBm to -30dBm) terminated or unterminated	: 50Hz to 5kHz ≤0.0015% (-96dB) 20Hz to 20kHz ≤0.003% (-90dB) 20kHz to 50kHz ≤0.006% (-84dB) 50kHz to 100kHz ≤0.01% (-80dB) 10Hz typically ≤0.03% (-70dB)

Supplementary Data for Signal Source:

Output Configuration Unbalanced	: *Output BNC connector may be referenced to chassis or floated above ground ±30V peak. (≤0.5 μf between low output terminal and chassis in float mode)*
Balanced	: *Output connector is tip-ring-sleeve telephone style jack (mates with WE-310 plug or equivalent). Output is transformer coupled to provide isolation and balance. Center tap may be referenced to chassis or floated above ground ±30V peak. (≤0.5μf between output center tap and chassis in float mode)*
Output DC Offset	: *Unbalanced : ≤0.1% of output AC rms voltage* *Balanced : ≤0.1% of output AC rms voltage*

DISTORTION MEASUREMENT (THD + N)
(specifications apply to both balanced and unbalanced input except where noted) :

Fundamental Frequency Range	: 10Hz to 100kHz in four overlapping ranges
Input Level Range	: +40dBV to -30dBV (+42dBm to -28dBm) (100V rms to 30mV rms)
Measurement Bandwidth	: 10Hz to 300kHz ±3dB
Accuracy (harmonic measurement)	: Fundamental 20Hz to 20kHz : ±1dB Fundamental 10Hz to 50kHz : ±2dB Fundamental 50kHz to 100kHz: ±3dB
Residual THD + N Input signal within top third of meter scale in LEVEL mode and signal >0dBV (1Vrms)	: 50Hz to 5kHz, 30kHz BW : ≤0.0008%(-102dB) 10Hz to 10kHz, 80kHz BW : ≤0.0015% (-96dB) 10kHz to 50kHz, full BW : ≤0.003% (-90dB) 50kHz to 100kHz, full BW : ≤0.006% (-84dB)

Supplemental Data for THD + N Measurement:

Fundamental Rejection	: *Typically 10dB below specified residual THD of instrument or actual signal THD, whichever is greater.*

DISTORTION MEASUREMENT (IMD)

(requires option 006. Specifications apply to both balanced and unbalanced input except where noted.)

Function : SMPTE/DIN Mode	:	Measures AM modulation of HF signal by LF signal as a percentage or ratio of HF signal
CCIF Mode	:	Measures difference frequency component ($F_1 - F_2$) expressed as a percentage or ratio of high frequency twin-tone composite signal

Frequency Range		
SMPTE/DIN	:	Low frequency : 10Hz to 500Hz High frequency : 2kHz to 100kHz
CCIF	:	Mean frequency : 2kHz to 100kHz $F_1 - F_2$: 10Hz to 1kHz
Input Level Range	:	Same as THD
Amplitude Mix		
SMPTE/DIN	:	1:1 to 5:1 (LF:HF)
CCIF	:	1:1 ±10%
Residual Distortion	:	
SMPTE/DIN (LF 20Hz to 200Hz, HF 5kHz to 100kHz, mixed at 4:1)	:	≤0.003% (-90dB)
CCIF (5kHz to 100kHz, $F_1 - F_2$ = 20Hz to 500Hz mixed at 1:1)	:	≤0.003% (-90dB)
Accuracy (same conditions as residual distortion specifications above)	:	±1dB (±10%)

LEVEL/NOISE MEASUREMENT FUNCTION

(specifications apply to both balanced and unbalanced input except where noted)

Maximum input level	: +40dBV, (+42dBm, 100V rms)
Minimum signal reading LEVEL mode	: -70dBV (-68dBm, 0.3mV)
LOW PASS or BAND PASS mode	: -130dBV, (-128dBm, 0.3μV)
Bandwidth (-3dB)	: 3Hz to ≥300kHz

Residual Noise (source resistance ≤1k ohm):

Low Pass Mode:	
F_c ≤5kHz	: ≤-120dBV (1μV)
F_c ≤100kHz	: ≤-110dBV (3μV)
Band Pass Mode (12% BW) :	
F_c ≤1kHz	: ≤-120dBV (1μV)
F_c ≤100kHz	: ≤-100dBV (10μV)

Accuracy, LEVEL Mode Input Signals -60dBV (1mV) or greater	: 20Hz to 20kHz : ±2% (±0.3dB) 10Hz to 100kHz : ±4% (±0.5dB)

Common Characteristics, measurement section. (Applies to unbalanced input except where indicated.)

Input Impedance	: 100k ohms ±2% shunted by ≤100pf
Balanced Input	: 100k ohms ±2% each side to ground shunted by ≤200pf
Common Mode Rejection (balanced input)	: ≥40dB at 50 or 60Hz
dB Relative Control range	: ±12dB

Supplemental data for measurement section:

Meter Detection	*: True rms for signals with crest factor ≤3*
Meter Scales	*: dBm (ref 1mW, 600 ohms) -linear + 4dBm to -8dBm* *dBV (ref 1V rms) - linear + 2dBV to -10dBV* *Volts, percent-logarithmic 4 to 1 and 1.2 to 0.3*
Indicators	*: Two input level LEDs indicate over or under range in DISTORTION mode to facilitate correct setting of INPUT level control. Low LED warns when input level is below minimum input level (ie. -30dBV).* *Two tuning LEDs facilitate tuning of analyzer in THD mode when using an external oscillator*
Monitors	*: INPUT MONITOR provides scaled presentation of input signal. Signal level approximately -10dBV (316mV rms) for full scale signals and INPUT control settings of +40 to -20dB. Proportionately lower at lower settings. Source impedance 600 ohms ±10% .* *DISTORTION MONITOR provides scaled presentation of function being measured: input signal in LEVEL mode, distortion components in DISTORTION modes and filtered signal in LOW PASS or BAND PASS modes. Signal level approximately -10dBV (316mV rms) with full scale readings in both LEVEL mode and for measured value. Proportionately lower with lower levels. Source impedance 600 ohms ±10% .*

FILTERS:

400Hz High Pass (standard)	: -3dB at 400Hz ±5%, at least 40dB rejection at 60Hz
30kHz Low Pass (standard)	: -3dB at 30kHz ±5%
80kHz Low Pass (standard)	: -3dB at 80kHz ±5%

Supplementary Data for Filters:

Filter Characteristics of three standard filters described above	*: 3 pole Butterworth response (18dB/octave)*
Auxiliary Filter	*: 16 PIN socket to accept various filters available from Amber including ANSI/IEC A Weighting, CCIR and others. Details provided for user construction of custom filters.*
Band Pass Level Mode	*: Tuneable band pass filter with a bandwidth of approximately 12%. User changeable from 10% to less than 1% with single resistor change.*
Low Pass Level Mode	*: Low pass filter with tuneable cutoff point. Slope characteristics: 12dB per octave. Pass band ripple $\leq$3dB.*
Frequency Range Band Pass & Low Pass Modes:	*10Hz to 100kHz (tracks oscillator within $\pm$ 3%).*

General:

Temperature, operating:	0^0C to $+50^0$C
Temperature, storage	: -40^0C to $+75^0$C
Humidity Range	: <95% RH, 0^0C to $+40^0$C
Power Requirements	: Instrument operates from 14V AC, 40VA nominal provided by external (supplied) AC mains transformer. Standard transformer operates from 120V rms +5%, -10%, 50/60Hz. Option 003 provides transformer with multi-taped primary for connection to 100, 120, 220 or 240V rms +5%, -10%, 48 to 62Hz. Instrument may also be powered from an external source of DC nominal 12.5V to 18V at <2A.
Internal Battery (option 001)	: 12V rechargeable battery and charging system provide 1.5 hours or more of instrument operation after full charge. Two rate charger automatically switches between high charge and float mode.
(option 002)	: Same as above but provides 3 hours or more.
Dimensions (excluding bottom feet and front and rear panel projections):	
H x W x D	: 114 mm x 292 mm x 356 mm (4.5 in x 11.5 in x 14 in)
Weight	: Basic instrument : 5.7 kg (12.5 lbs) As above with 001 Battery : 6.8 kg (15 lbs) As above with 002 Battery : 8.2 kg (18 lbs)

Note : Values shown in SPECIFICATIONS are warranted specifications. SUPPLEMENTARY DATA shown in italics are non-warranted data supplied for information only.

All specifications subject to change without notice.

1.3 OPTIONS

Note : All 3501 instruments will have the same outward appearance, that is, the front panel will incorporate provision for all options. Thus although the front panel pushbutton for IMD or BALANCED operation may be present, it does not necessarily mean that the internal module is present to provide the function. The front panel and internal wiring are present to facilitate future instrument upgrade by the user.

To determine the instrument configuration at the time of initial factory shipment note the five digit model number suffix recorded on the serial number plate on the rear panel of the instrument. Below is a table showing the option configuration for various model numbers.

3	5	0	1	—	0	0	0	0	0

POWER OPTION	INTERFACE	MEASUREMENT	AUXILIARY FEATURES	AUXILIARY FILTER
0 120 VAC	0 UNBALANCED	0 THD only	0 NONE	0 NONE
1 120 VAC +001 BATTERY	1 BALANCED IN 004	1 IMD 006	1 358 FREQ COUNTER	1 ANSI 'A"
2 120 VAC +002 BATTERY	2 BALANCED OUT 005	2	2	2 CCIR
3 100/120/220/ 240V AC	3 BAL IN/OUT 004 + 005	3	3	3 IHF/IEEE Band Pass
4 100/120/ 220/240V AC 003 + 001 BATT	4	4	4	4 Psophometric
5 100/120 220/240V AC 003 + 002 BATT	5	5	5	5 C Message

001: RECHARGEABLE BATTERY, AC ADAPTER/CHARGER

Provides an internal 12V rechargeable battery and a DC-to-DC inverting power supply to generate the two isolated bi-polar power rails to power the generator and measurement circuits. Power supply also includes a battery charging circuit and voltage level detector to automatically shut off instrument when battery voltage falls to approximately 8V. (Provides approximately 1.5 hours or more of discharge time after full charge.)

002 : EXTENDED BATTERY and CHARGER

Similar to option 001 above but provides approximately twice the discharge time (about 3 hours).

003 : 100, 120, 220, 240 VAC MAINS ADAPTER/CHARGER

Replaces 120VAC adapter normally supplied with one suitable for international use.

004 : BALANCED INPUT

Provides an active differential input configuration for use in professional/broadcast systems or measurements of non-ground referenced sources. Also useful to break ground loops.

005 : BALANCED OUTPUT

Provides a floating/balanced output capable of up to +28dBm drive into a 600 ohm load. Front panel switches select Balanced or Unbalanced, Floating or Grounded and Terminated or Unterminated.

006 : INTERMODULATION DISTORTION MEASUREMENT FACILITY

Provides second (Low frequency) oscillator and mixing circuitry to provide twin-tone generator signal and intermodulation distortion measurement filters to be used with 3501 meter ciruits. Can generate SMPTE or DIN standard test signal and measure SMPTE, DIN, IHF and CCIF type of IMD distortion. Generator HF component can be varied from 2kHz to 100kHz.

model 354 : WEIGHTING NETWORK/FILTER KIT

Provides five popular plug-in filter networks and five unbuilt headers and covers for construction of custom networks.

Model 358 : High Resolution Frequency Meter

This option adds a digital frequency meter to the 3501 to permit accurate measurement of either internal or external signals. A frequency multiplier provides high resolution (0.1Hz) and fast update (100mS) for convenient low frequency use. Auto ranging, input selection

and special modes make the 358 both convenient and simple to use. Mounts in a one inch overbridge on the 3501 cover. May be retrofitted to existing units.

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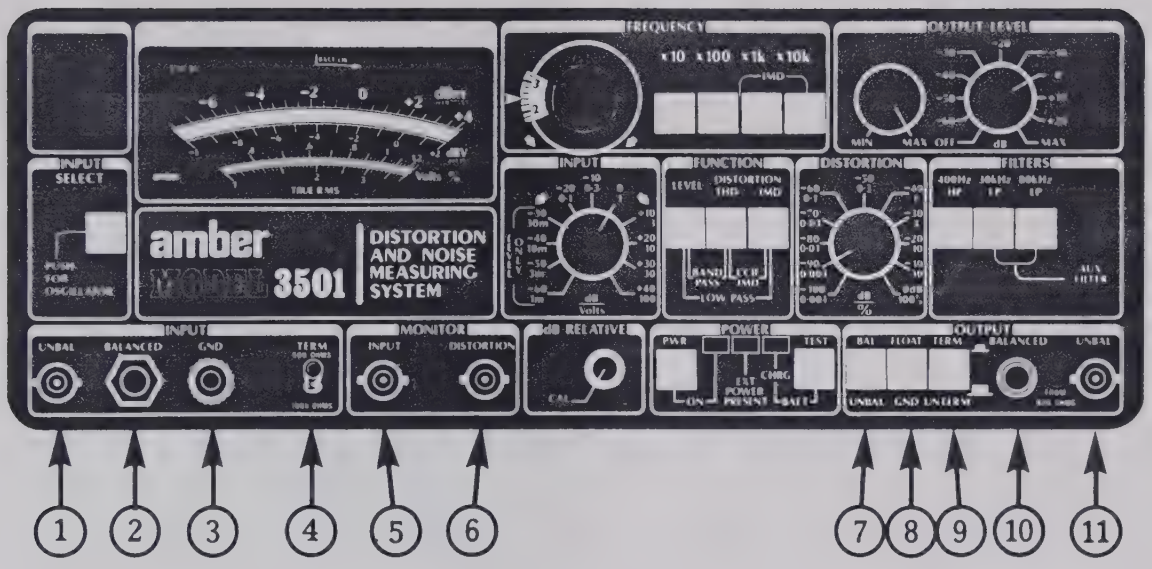
SECTION 2

OPERATING INSTRUCTIONS

3501 EXTERNAL CONNECTIONS



INPUT CONNECTIONS

Connect unbalanced or single ended source to 1.

If option 004, BALANCED INPUT, is provided, connect balanced or non-ground referenced sources to 2. Floating or bridged power amplifiers would connect here. This differential input can also be used to break ground loops: connect external source to tip, external ground to ring and input cable shield to sleeve.

OSCILLOSCOPE CONNECTIONS

Use dual trace oscilloscope. Connect trace A to 5 to view fundamental, trigger on this trace. Connect trace B to 6 to see distortion components.

OUTPUT CONNECTIONS

Connect inputs of unbalanced or single ended devices to be tested to 11.

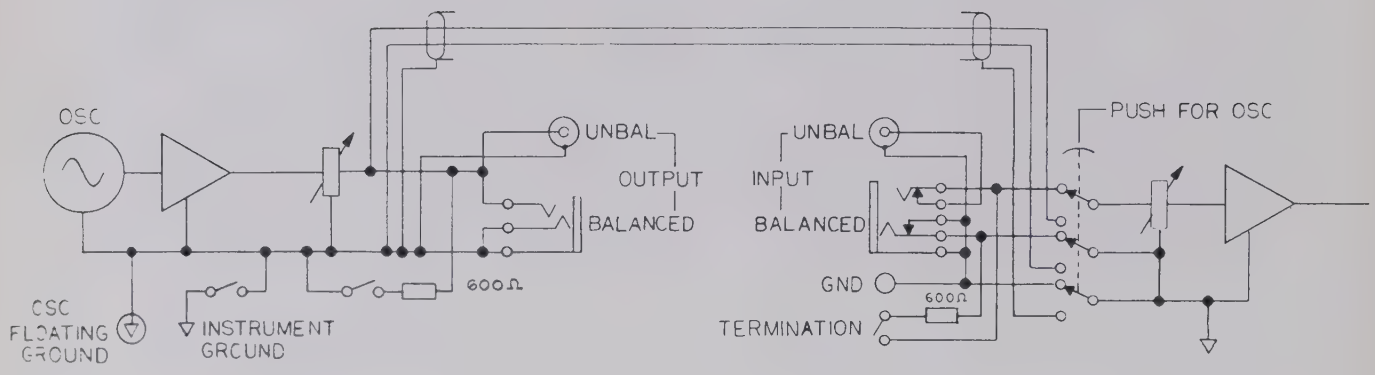
If option 005, BALANCED OUTPUT, is provided, connect balanced devices to 10 (use a telephone style WE-310/PJ051 tip-ring-sleeve plug).

Select balanced or unbalanced mode at 7.

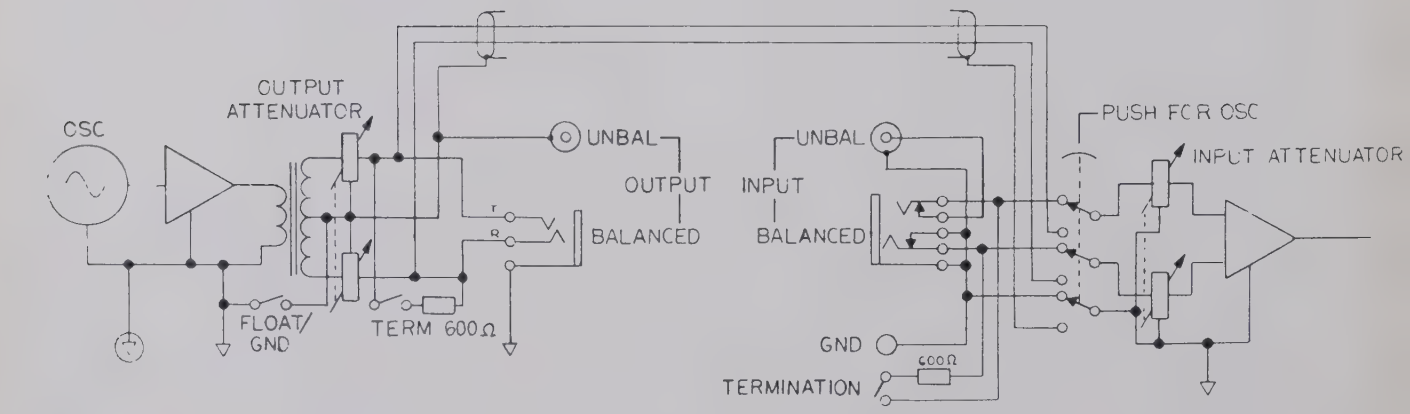
Select grounded output or floating output at 8. Use grounded mode if 3501 being used as an oscillator only. If analyzer section is also connected to device under test, use FLOAT mode as ground will be via input ground connection to 3501.

9 terminates oscillator output in 600 ohms or leaves output unterminated.

INSTRUMENT GROUND SYSTEM

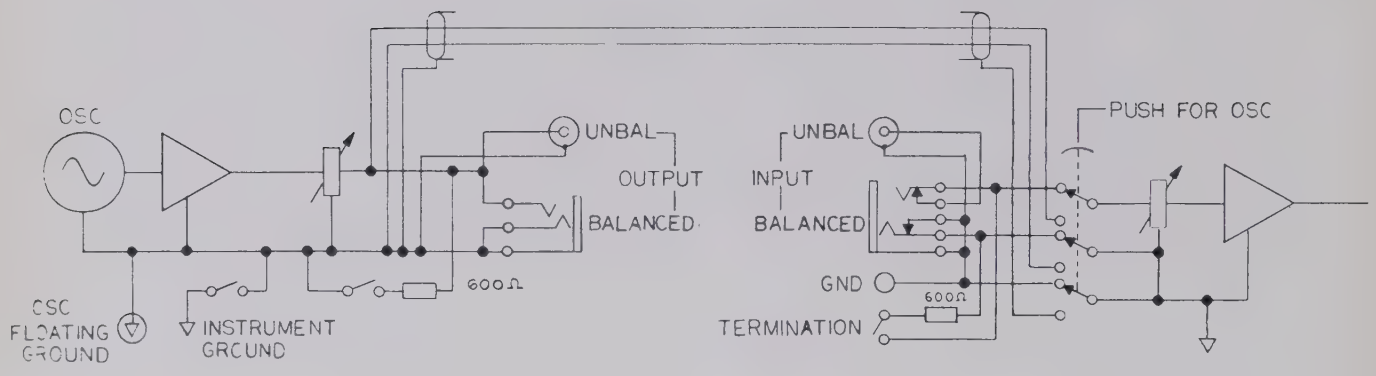


UNBALANCED MODE. This is a simplified schematic of INPUT and OUTPUT connections in the UNBALANCED MODE. INSTRUMENT GROUND is chassis.

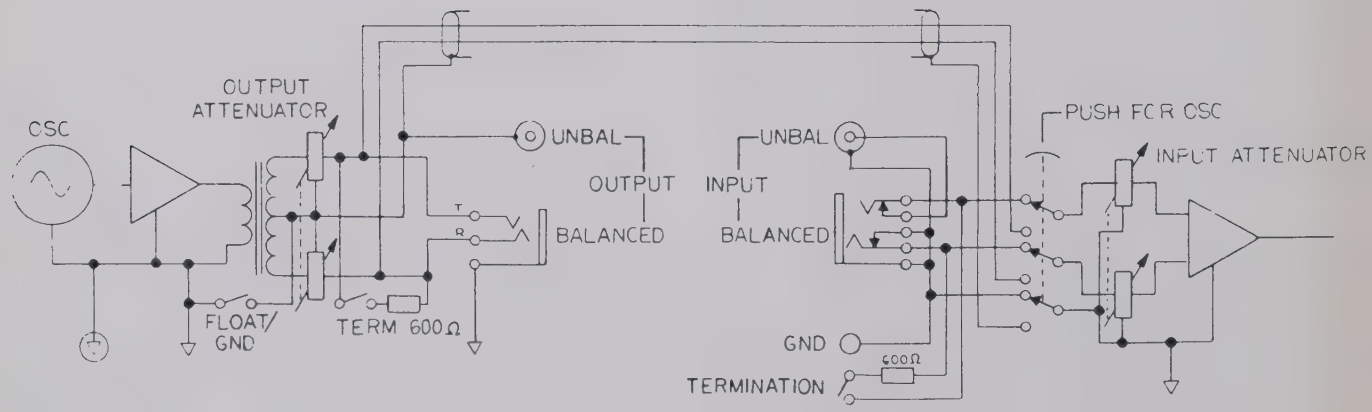


BALANCED MODE. This is a simplified schematic of INPUT and OUTPUT connections in the BALANCED mode (provided options 004 and 005 are installed).

INSTRUMENT GROUND SYSTEM



UNBALANCED MODE. This is a simplified schematic of INPUT and OUTPUT connections in the UNBALANCED MODE. INSTRUMENT GROUND is chassis.



BALANCED MODE. This is a simplified schematic of INPUT and OUTPUT connections in the BALANCED mode (provided options 004 and 005 are installed).

1) INPUT SELECT PUSHBUTTON. Selects input to analyzer. Push in to read actual GENERATOR OUTPUT LEVEL for any value of external load. Release to read the INPUT signal .

2) INPUT control determines input sensitivity. Set for an on-scale meter reading in the LEVEL mode or to extinguish the HI and LO LED warning indicators in distortion modes.

3) FREQUENCY vernier control. Sets significant digit of oscillator and analyzer frequency.

4) FUNCTION pushbutton group. Basic functions of LEVEL, TOTAL HARMONIC DISTORTION and SMPTE INTERMODULATION DISTORTION are set by pushing one of the three buttons. Special functions of BAND PASS LEVEL, LOW PASS LEVEL & CCIF INTERMODULATION DISTORTION are selected by pushing two buttons together. (Note IMD functions operational only if option 006 is installed.)

5) FREQUENCY RANGE pushbutton selects multiplier of number set by rotary vernier knob.

6) DISTORTION control determines meter sensitivity. Set for an on-scale meter reading in the DISTORTION mode or the BAND PASS/LOW PASS mode.

7) Output control provides a nominal 12dB variation of output level.

8) OUTPUT attenuator sets the nominal 10dB step of output range. Source impedance is 600 ohms in all positions except MAX. When output is loaded with 600 ohms, all steps except MAX will be 10dB. OFF position shuts down oscillator but retains 600 ohm source impedance.

9) FILTER pushbutton group. Chooses appropriate selection from four available filters. Three standard filters selected by pushing in one or more of the three buttons. Fourth (AUX FILTER) filter position selected by pushing in second and third button simultaneously (only functional if optional fourth filter installed).

10) UNBALANCED INPUT connector. Use for single ended sources. Shell of BNC connector is normally connected to chassis but floats when PUSH FOR OSCILLATOR is pushed. Input impedance set by (13) is 100k ohms or 600 ohms in parallel with about 100pf.

11) BALANCED INPUT connector. Tip, ring and sleeve telephone-type connector for balanced inputs. Sleeve is chassis when INPUT is selected. Inserting a plug disconnects the UNBAL input. (Balanced mode functional only if option 004is installed.)

12) GROUND post is normally connected to chassis but floats when PUSH FOR OSCILLATOR is pushed.

13) INPUT TERMINATION switch selects input impedance for both balanced and unbalanced inputs.

14) INPUT MONITOR connector presents a scaled replica of INPUT signal after INPUT control.

15) DISTORTION MONITOR connector presents a scaled replica of signal being measured: the input signal in LEVEL, distortion residual components in DISTORTION and the selective filter output in BAND PASS or LOW PASS.

16) dB RELATIVE control allows meter reading to be offset up to ±12dB to set an arbitrary zero dB reference. (Useful for frequency response and signal-to-noise measurement.)

17) POWER ON/OFF pushbutton. Turns instrument on and off using either internal (battery) or external (transformer) power source. Will turn off automatically on low battery.

18) POWER indicator. Red LED indicates unit is ON. When optional battery reaches last 10% of life, LED starts to blink. Blinking duty cycle increases as battery nears end of discharge until instrument automatically shuts off.

19) EXTERNAL POWER PRESENT indicator. Green LED indicates the presence of adequate external power source, typically AC mains via the wall plug transformer. Will extinguish if mains voltage is too low or internal fuse opens.

20) CHARGE indicator. Orange LED indicates high-charge rate of battery charging. When battery is fully charged, indicator will extinguish and charger will switch to a float charge mode. High-charge rate may require instrument to be switched off. (Functional only if option 001 or 002 battery is installed.)

21) BATTERY TEST pushbutton. Switches measurement meter to battery to measure battery charge condition. Should be pushed with instrument turned ON. A reading of mid-scale ("BATT OK") or greater indicates satisfactory battery charge. Deflection is approx. proportional to charge life available. (Meaningful only if option 001 or 002 battery is installed.)

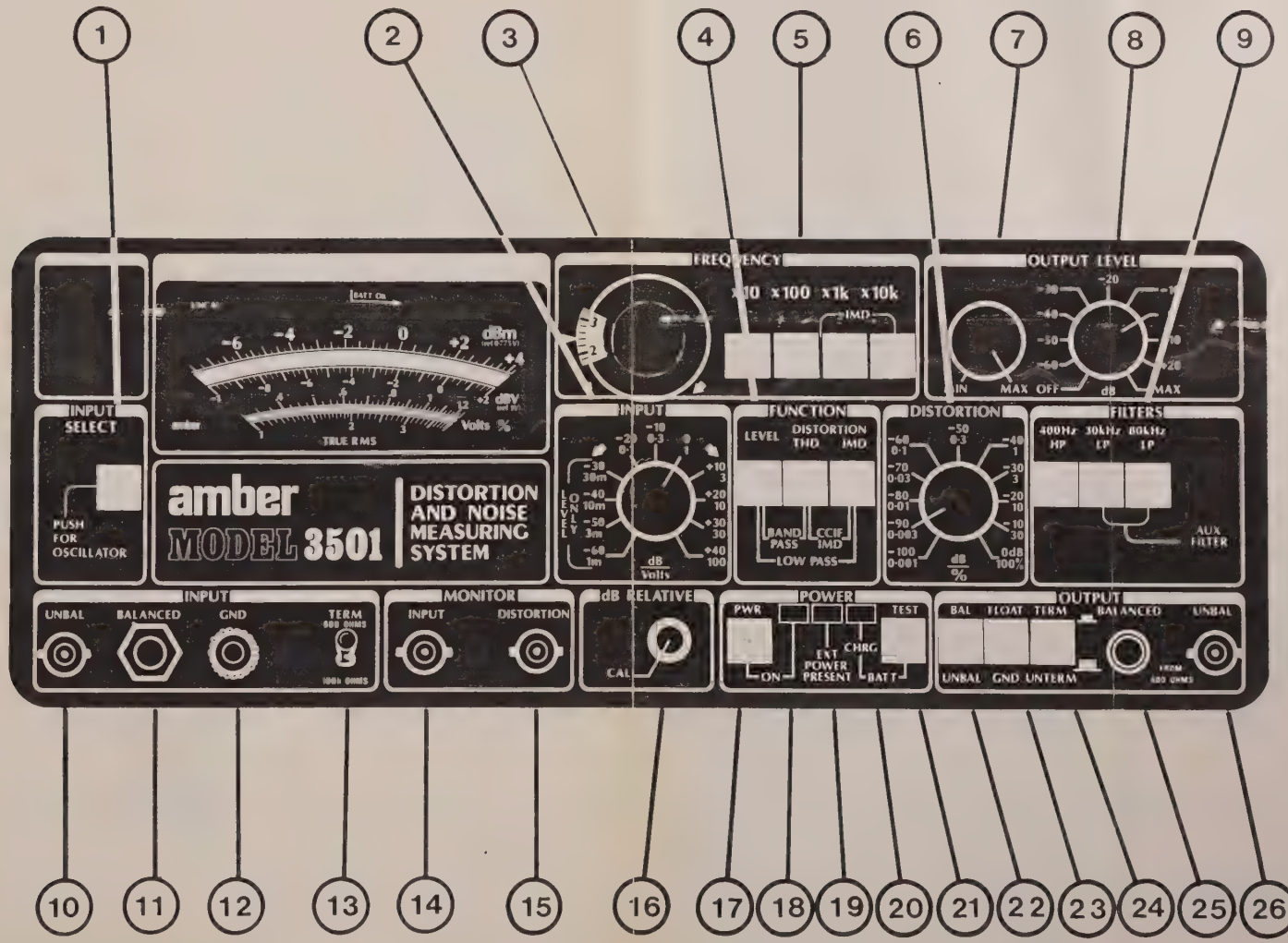
22) BALANCED/UNBALANCED pushbutton. (Valid only if option 005, Balanced Output, is provided.) With button out, generator output is present on UNBAL BNC connector and in a single ended mode on the tip-ring-sleeve jack. With button in, optional balancing system is inserted and a balanced output appears at the T-R-S jack.

23) FLOAT/GROUND pushbutton. In unbalanced mode, button in sets shell of BNC and sleeve-ring of jack to a floating condition with respect to instrument chassis and input ground. With button out, all grounds are common. In balanced mode button in sets BAL out to float condition. Sleeve is ground and center tap of output floats with respect to instrument ground. With button out, sleeve and center tap are connected to instrument common ground.

24) TERMINATE/UNTERMINATE pushbutton. With button out, output is unterminated. With button in, output is terminated (ie. loaded with) 600 ohms. Note that output source impedance is 600 ohms at all times except if OUTPUT ATTENUATOR is set to MAX when output source impedance is approximately 300 ohms unbalanced, <100 ohms balanced.

25) BALANCED output jack. Tip, ring and sleeve telephone type jack provides balanced output in balanced mode (with option 005) or single ended output (tip and sleeve) in unbalanced mode.

26) UNBALANCED output connector. BNC connector provides unbalanced output. Disconnected in BALANCED mode.


1
2
3
4
5
6
7
8
9
INPUT SELECT
PUSH FOR OSCILLATOR
amber
MODEL 3501
DISTORTION AND NOISE MEASURING SYSTEM
FREQUENCY
x10 x100 x1k x10k
IMD
OUTPUT LEVEL
IN MAX OFF
dB
MAX
INPUT
LEVEL ONLY
dB Volts
FUNCTION
LEVEL
DISTORTION
THD IMD
BAND PASS
CCIF IMD
LOW PASS
DISTORTION
dB %
FILTERS
400Hz HP
30kHz LP
80kHz LP
AUX FILTER
INPUT
UNBAL
BALANCED
GND
TERM 600 OHMS
MONITOR
INPUT
DISTORTION
dB RELATIVE
CAL
POWER
PWR
ON
EXT POWER PRESENT
CHRG
BATT
TEST
OUTPUT
BAL
FLOAT
TERM
BALANCED
UNBAL
UNBAL GND UNTERM
10
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2. OPERATING INSTRUCTIONS

2.0 INTRODUCTION

This section contains detailed operating instructions for use of the model 3501 instrument. It describes the general philosophy of the instrument, description and use of its operating controls, interface to the device under test and any required external equipment.

2.1 PREPARATION FOR USE

The model 3501 is powered by an external source of nominal 14V AC. This is supplied by an external mains transformer. In its standard form, for North American use, this is a "wall plug" box designed to be plugged into a standard nominal 115V AC wall receptacle. This transformer has internal protection against failure by means of an automatically resetting thermal breaker in series with the output to protect against shorts. A captive cable terminates in a four-pin DIN style locking connector. This plug should be connected to the mating connector on the rear panel of the 3501.

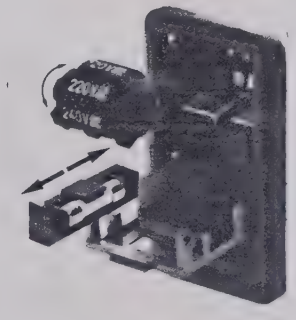


Fig 2.1 **Changing Voltage Taps**
Option 003 International AC Mains Transformer

As an option, an international AC mains transformer may be provided (option 003). This is a box containing the mains to 14V AC transformer, a line fuse, a line voltage selection switch and an IEC standard AC mains receptacle. An AC line cord with a mating IEC plug at one end will also be provided. The other end is prepared for the user's selection of AC mains plug. This cable follows the European standard color code.

Before use set the voltage selector to the appropriate setting. This is done by unplugging the mains power cord, pulling down on the access door, rotating the voltage selection drum to the appropriate orientation and closing the access door. (See fig 2.1)

The following table gives the mains voltage range for each nominal selection:

NOMINAL VOLTAGE	OPERATING RANGE (+5% -10%)	FUSE (Slow Blow) (primary)
100 Volts	90 to 105 Volts	0.5A S.B.
120 Volts	108 to 126 Volts	0.5A S.B.
220 Volts	198 to 231 Volts	0.25A S.B.
240 Volts	216 to 252 Volts	0.25A S.B.

This international mains transformer supply also contains a captive power cord terminating in a four-pin DIN style locking connector. Plug this connector into the mating receptacle on the rear panel of the 3501.

The instrument may also be equipped with an optional rechargeable battery and charger system.

There are two or three internal fuses in the instrument. One is on the external power input line. A failure of this fuse will prevent the instrument from turning on unless there is an internal, charged battery. It will also inhibit battery charging. The second fuse is on the INPUT line and should only fail if the input signal exceeds the capabilities of the instrument. This would occur if the INPUT control were set to +10dB/3V or lower and the input signal level were +30dBV/40V or higher. If the balanced input option has been provided, two input fuses will be included, one in each input.

If either or both of the INPUT fuses open, the signal will be interrupted directly after the INPUT connector and will not appear at any MONITOR output or on any measurement function. To change the fuse refer to the disassembly instructions in section 6. The fuses are located on the input/meter board in the center of the instrument. Access is via the lower cover.

The power fuse is easily accessible by removing the top cover. It is located on the linear power board mounted on the rear panel and may be changed from the top.

2.2 SYSTEM DESCRIPTION

The model 3501 Distortion and Noise Measuring set contains two electrically separate but mechanically interlocked sections: a Generator and a Measuring system. As such, it is completely able to perform measurements without the use of additional equipment although an oscilloscope is very useful.

The system will measure wide-band signal level, wide-band noise, total harmonic distortion, band limited noise and crosstalk. By extension, it can measure frequency response, noise spectrum, distortion versus frequency and distortion versus level.

The instrument contains a precision ultra low distortion sine wave oscillator followed by a power amplifier and output attenuator. This generator is able to generate the test signals for all the measurements possible in the measuring system. (An exception is CCIF IMD Section 2.13.3.)

Signal and noise levels are measured by a precision variable gain amplifier followed by a true rms detector and analog meter. It is capable of operation over a wide dynamic range of up to 160dB or 100 million-to-one.

The primary function of the instrument is to measure total harmonic distortion. In fact, the more precise description of the resulting measurement is "Total Harmonic Distortion plus Noise". It does this by sending an essentially pure single frequency to a device under test, eliminates this fundamental frequency from the received signal output of the device under test, measures everything that is left and presents this amplitude as a ratio of the total received signal.

For example, assume a test frequency of 1kHz. The 3501 will generate this signal with harmonics greater than 100dB down resulting in an essentially pure signal. For simplicity, assume the device under test is unity gain and we wish to measure THD at 0dBV, i.e. a 1V level. The generator will provide the 1kHz, 0dBV signal to the input of the device under test, the 0dBV signal output will be fed to the input of the 3501. A very deep notch filter (band reject filter) will provide over 100dB of rejection of the 1kHz fundamental. The non-linearities of the device under test will have added components at 2kHz, 3kHz, 4kHz, etc. The RMS meter of the 3501 will measure the amplitude of the root mean sum of these, compare this amplitude to that of the fundamental and display the result as a percentage or dB ratio. If the amplitude of the rms sum of the harmonics were 1 mV in this example, the meter would indicate 0.1% or -60dB.

Since the measuring circuits are measuring the total bandwidth minus only the small fundamental area, they will also measure noise along with the harmonics. In many cases, the noise will be below the harmonics and the

measurement will be very close to the true harmonic distortion. In other cases, the noise will be higher and thus the measurement will actually be mostly noise and very little distortion. The use of an oscilloscope to monitor the distortion residual will assist the user in qualifying the measured result. Also see the section on Filters 2.7 following.

2.3 RMS DETECTION

Distortion and noise measurements will generally involve complex waveforms. Average-responding meters, which are usually calibrated in rms for a pure sine wave, will give significant errors when attempting to measure these complex waveforms. For this reason, the 3501 employs a precision rms detector in the measurement circuits.

Certain waveforms can yield an error of over 10% when measured with an average responding detector. The rms measuring circuits of the 3501 will provide an accurate measurement of signals with crest factors as high as 10 full scale (see Section 2.5.2 following) This assures accurate indication of distortion and noise signals.

2.4 SIGNAL GENERATION

The 3501 contains an ultra low distortion sine wave oscillator, an output power amplifier and an output attenuator. Also included are facilities to measure the output signal level using the 3501 meter.

The generator has a frequency range of 10Hz to 100kHz covered in four overlapping decade ranges. It has an amplitude range of +20dBm to -60dBm unbalanced or up to +28dBm balanced and terminated. It provides continuous tuning and continuous level selection over its full operating range. Although ultra low distortion, it exhibits extremely fast amplitude settling time even at low frequencies. Output source impedance of the generator is 600 ohms at all but one attenuator setting including OFF. The exception is the MAX setting of the OUTPUT ATTENUATOR where the output source impedance is approximately 300 ohms unbalanced or <100 ohms balanced. The output low terminal (BNC shell) is isolated from input low and chassis ground when in the FLOAT mode.

Frequency selection is made using the vernier drive rotary control and four-button switch bank in the FREQUENCY area of the panel. Actual frequency is the indication on the rotary dial multiplied by the number on the selected range. Some overlap is provided at each end of the rotary control to ensure that all frequencies within the instrument range are available.

Where the same frequency appears in two ranges (example 100Hz, 1kHz, 10kHz) the preferred selection is the lower range with the rotary control set to 10. (Example, 1kHz found by 10 x 100 rather than 1 x 1k; residual distortion of the instrument is slightly lower in this mode.)

Output signal level selection is made using the upper right rotary control and the rotary attenuator switch. Actual output level can be measured by pushing the PUSH FOR OSCILLATOR button at the left of the meter. This connects the input metering circuit directly across the output load for precise send-level measurements.

An OFF switch position in the OUTPUT ATTENUATOR provides a convenient means of making signal-to-noise measurements. In the OFF position the output connector is disconnected from the output power amplifier and connected to a 600 ohm resistor. For added safety, the oscillator circuit is disabled to avoid any chance of signal leak-through.

2.4.1 BALANCED OUTPUT

As an option, the instrument may be provided with a balanced output facility. Two output connectors are provided - a BNC for unbalanced output and telephone style tip-ring-sleeve jack for balanced output. This will permit convenient interface to conventional patch panels in systems applications. (The T-R-S jack mates with PJ-051 or WE-310 type plugs.)

Three pushbuttons in the OUTPUT section allow choice of output configuration:

a) BAL/UNBAL sets the output to unbalanced single ended mode or the balanced mode. In the balanced mode, an output transformer is used to provide maximum isolation and true balance. Electronic corrective circuitry (patent pending) significantly reduces the distortion contribution of the transformer.

b) FLOAT/GROUND. In the unbalanced mode this allows the oscillator to float with respect to instrument (analyser) ground. In the balanced mode this grounds or floats the transformer secondary center tap.

c) TERM/UNTERM. In the TERM mode this terminates the output with a 600 ohm load resistor.

2.5 LEVEL MEASUREMENT (VOLTMETER OPERATION)

The 3501 will measure signal level over the frequency range of 10Hz to approximately 300kHz and from +40dBV (100 volts) to -60dBV (1mV) full scale. See Section 2.8 following for signals below -60dBV.

To measure signal level, connect the signal to the appropriate INPUT connector, select LEVEL in the FUNCTION group and turn the INPUT rotary control until the meter reading is on scale. (Note that the HIGH/LOW warning LEDs only function in the DISTORTION mode.)

The actual signal level is determined by adding the meter reading in dBV or dBm to the INPUT control selection. Or, to find the reading in volts, use the 1 or 3 scale on the meter as appropriate and the range indicated by the INPUT control. For example, if the INPUT control is pointing to 0.03, use the 3 scale. If the meter pointer shows 2.3 in this example, the actual level is 0.023 Volts or 23mV.

The input impedance is 100k ohms shunted by 100 pf or less. This presents a sufficiently high impedance load to most circuits to achieve an accurate reading. If the circuit being measured has a high source impedance (over 1k ohm), a correction factor will have to be used due to the loading of the 100k ohm input impedance.

The input preamp contains an active protection circuit which is designed to protect the sensitive input components from signal overload and will cause a fuse to open. Since the instrument must measure very low distortion, simple conventional protection circuits are not useable and a sophisticated active circuit is employed instead. This circuit achieves all the parameters required but can cause difficulties under a particular (and unusual) circumstance. If the 3501 is turned OFF and connected across a source with a finite output impedance, the 3501 will induce distortion into this source. When the 3501 is not powered, the active protection network ceases to function and the input can look like a non-linear load.

For noise measurements the FILTERS may be used in the LEVEL mode. See Section 2.7 following.

2.5.1 BALANCED INPUT

The model 3501 may be equipped with an optional balanced or differential input. In this case a second input preamp and input attenuator are provided. This option permits measurement of non-ground referenced sources or balanced sources as found in professional and broadcast applications. With this option, two input connectors are provided - a BNC for the unbalanced input and a telephone style ring-tip-sleeve jack for the balanced input. The BNC connector is wired via the normalling contacts of the RTS jack. If no plug is inserted in the jack, one of the differential inputs is connected

to the BNC receptacle while the second input is grounded. An instrument input ground post is also provided. (This post is connected to chassis except it floats when the PUSH FOR OSCILLATOR button is pushed.)

An input termination switch is included to allow selection of input impedance. In the down position, the input impedance is 100k ohm to ground in parallel with less than 100 picofarad of capacitance. In the balanced configuration each input is 100k ohms to ground. With the toggle switch in the UP position, a precision 600 ohm termination resistor is added across the input (balanced) or from input to ground (unbalanced).

2.5.2 HIGH CREST FACTOR RMS MEASUREMENTS

The model 3501 has an automatic crest factor compensation facility. This optimizes the noise floor/crest factor capability trade-off that is always present in level measuring instruments.

If the DISTORTION control is set to -80dB/0.01% or lower, the instrument presumes a low crest factor as would be the case with a clean sine wave. In this case the signal amplitude in the preamp and following circuits is maximized to provide the best signal-to-noise performance. Conversely, if the DISTORTION control is set to -70dB/0.03% or higher, the internal signal level is lowered by 10dB giving greater crest factor handling capability.

All of the level correction required for this manipulation is transparent to the user and is handled automatically by the instrument. The only noticeable difference is the absolute level of the two MONITOR outputs which reflect this 10dB change.

If distortion is being measured, the compensation will be automatic. If only signal level is being measured, set the DISTORTION control to -70dB/0.03% or higher if the signal has a crest factor of greater than about 2. An example would be noise, narrow duty cycle pulse waveforms, signals with high value spikes superimposed, etc.

2.6 TOTAL HARMONIC DISTORTION MEASUREMENT

The model 3501 provides a complete THD measurement system by combining a low distortion signal source and an automatic distortion measurement facility. The latter may also be used with an external signal source when required.

When making THD measurements using the internal source, connect the 3501 and device under test as shown in Fig 2.6. (It is good practice to turn the oscillator output level to minimum before connecting.) It is suggested that an oscilloscope be used as shown to monitor the signals and verify the validity of the measurement. This will show any excessive noise, oscillation, interference or other potential source of error in the measurement.

Set the GENERATOR send level to the level required by the device under test using the procedure shown in Section 2.4 previous. Connect the 3501 OUPUT to the input of the device under test and its output to the 3501 INPUT. (In the case of audio power amplifiers of course, an external 8 ohm load is usually used.)

If it is necessary to first measure the signal level, proceed as in Section 2.5 previous. If not, push DISTORTION in the FUNCTION group. Turn the INPUT rotary control the appropriate direction if either of the HIGH or LOW red LEDs are on. The proper setting is when both of these are extinguished. Next, turn the DISTORTION rotary control until the meter gives an on-scale reading. The instrument will automatically and rapidly null to a final value as the control is rotated counterclockwise.

Observe the distortion residual components at the front panel MONITOR DISTORTION connector using an external oscilloscope. A typical waveform is one that has a shape close to the second or third harmonic (or a mixture) of the fundamental. A dual trace oscilloscope facilitates this observation. If the waveform exhibits a line synchronous component of 50 or 60Hz there is hum pickup in the test set-up. If a 100 or 120Hz component, it probably indicates an insufficiently filtered power supply in the device under test. See Section 2.7 following. Be cautious of high frequency components indicating RF pickup or device oscillation.

When using an external source, the analyzer can be easily tuned using the two LED arrows below the FREQUENCY rotary control. These indicate the direction the rotary control or the pushbutton range switches must be adjusted to properly tune the analyzer. It is only necessary to tune to within about 10% of the input signal to achieve lock and extinguish the lights. Note that the internal oscillator should be turned off (output attenuator counterclockwise) when using an external source to prevent interference due to coupling.

Note that the lowest absolute signal level for distortion measurement is -30dBV/30mV. The lowest effective INPUT control setting is -20dB/100mV. Lower positions of this control (-30 to -60) will not give any increased sensitivity in the distortion mode. If the signal level is too low for distortion measurement (i.e. below -30dBV/30mV) the low red LED will remain on even when the input control is turned fully CCW.

2.7 USE OF FILTERS

The 3501 contains four front panel selectable filters which can enhance the accuracy of many measurements (three are standard, one is optional). For example, if the device under test is picking up mains hum this will influence the measurement and give an erroneous DISTORTION reading. Although it is necessary to be aware of these offending signals, it is useful to be able to separate the DISTORTION and NOISE readings.

400Hz HIGH PASS FILTER (standard)

This is an 18dB per octave (60dB per decade) filter useful to eliminate mains hum and other low frequency noise from the measurement. Its 3dB point or corner frequency is 400Hz and it may be used on signals whose fundamental is above 300Hz or so. It will provide approximately 50dB attenuation of 50 or 60Hz interference.

LOW PASS FILTERS (standard)

These are 18dB per octave (60dB per decade) filters useful to eliminate noise, RF interference, high frequency oscillation and, in general, to reduce the measurement bandwidth to gain a few dB improvement on the 3501 noise floor. Their 3dB down points are 30kHz and 80kHz respectively. They may be used to improve distortion measurement with fundamentals below about 6kHz with the 30kHz filter and 20kHz with the 80kHz filter.

AUXILIARY FILTER (optional)

A fourth filter position is provided for optional specialized noise weighting. It is accessed by pushing both the 30kHz and 80kHz buttons together. A typical application for this filter would be an ANSI/IEC "A" weighting filter or CCIR noise weighting curve.

All four filter positions are plug-in networks and may be easily user changeable. Each filter socket is identical and may accept any of the standard or custom filters offered by Amber or constructed by the user. (See section 4) The filters are always available in any instrument mode. They should not be used in signal level measurement modes such as frequency response measurements. They may be used for noise measurements or to enhance THD distortion measurement. They should not be used in the IMD distortion mode.

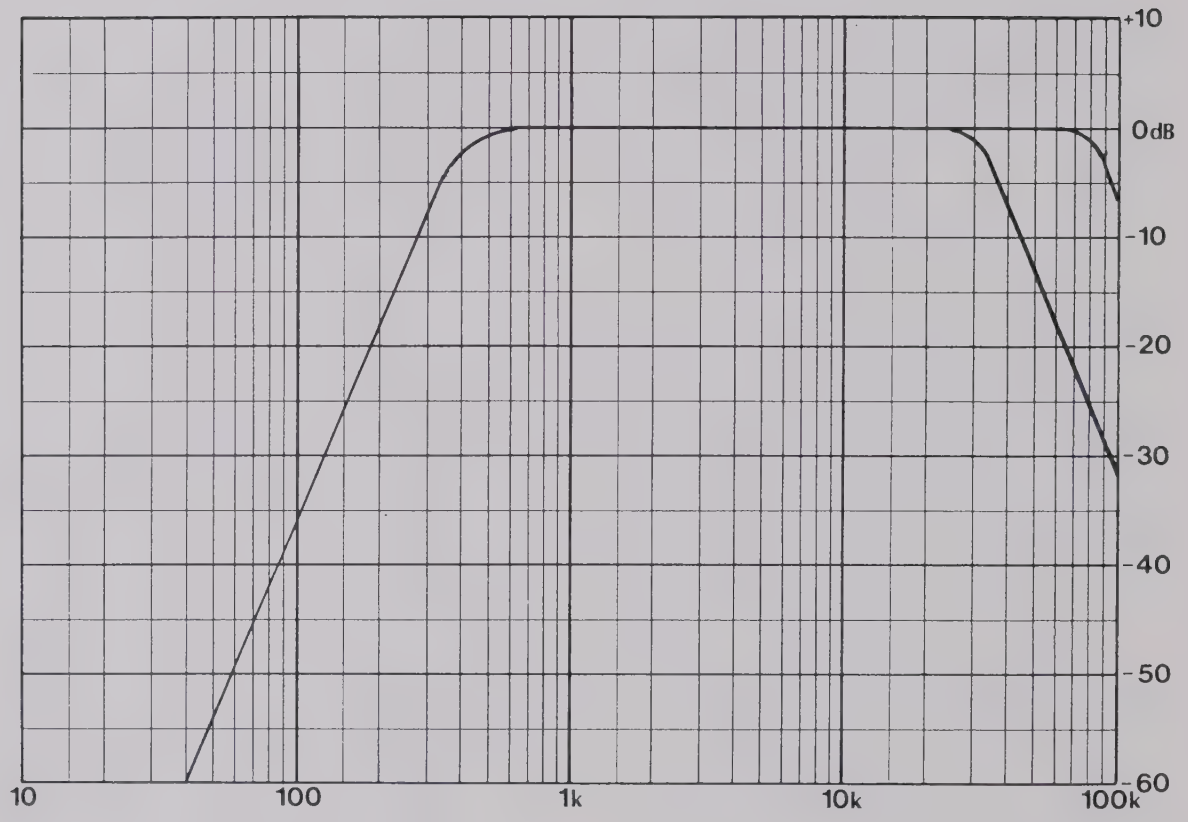


FIGURE 2.14 STANDARD FILTERS

Illustrated are frequency response plots of the three standard filters supplied: 400Hz High Pass, 30kHz Low Pass and 80kHz Low Pass. Each of the three filters is a 3-pole network giving 18dB per octave roll-off.

The 400Hz filter is useful to remove hum components or low frequency "flicker" noise. It can be used in THD measurements above about 500Hz. The two low pass filters can reduce high frequency bandwidth for noise measurements or for improved (and valid) THD measurements below approximately 10kHz or 25kHz respectively.

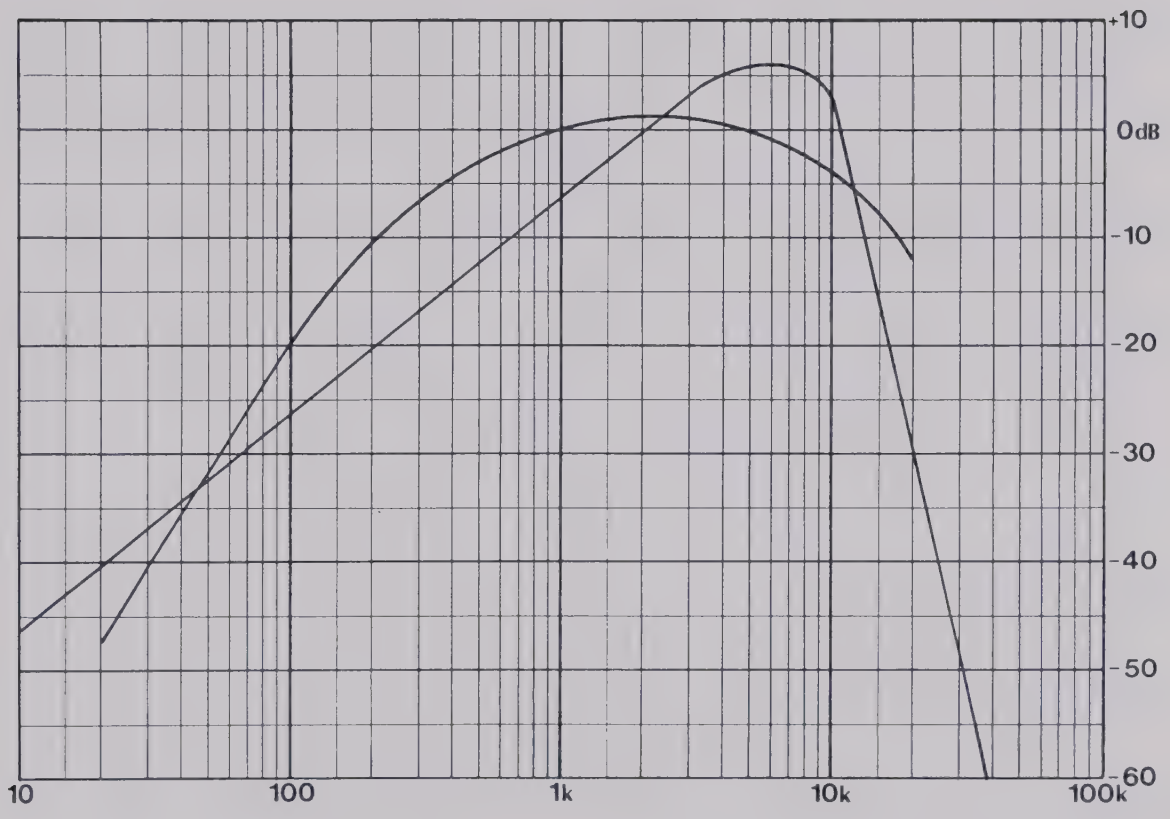


FIGURE 2.15 OPTIONAL FILTERS

Shown are frequency responses of some typical optional filter networks available. Usually, if one of these is provided, it would be located in the AUX FILTER position. Shown are the ANSI/IEC "A" Weighting curve and the CCIR 468-2 curve. This latter curve may be calibrated for either the 2kHz (DOLBY) reference shown or the 1kHz reference of the original specifications. (Standard factory calibration is 2kHz.)

These curves are typical of several available to meet various international noise weighting standards used in tape recorder, amplifier and system measurements.

2.8 NARROW BAND LEVEL MEASUREMENTS (Extended sensitivity voltmeter)

A unique and very useful feature of the 3501 is the narrow band level measurement capability. This enhances the signal level measurement capability for several measurement situations such as low level noise, crosstalk, signals near the noise floor and acoustic applications.

When the first two FUNCTION push buttons are pushed IN, a band pass filter is inserted in the level measurement path. This configures the instrument as a frequency selective voltmeter enabling it to read signal or noise level in a particular frequency band. The center frequency of this band-pass filter is selected by the FREQUENCY controls and tracks the generator frequency.

The shape of the filter is nominally about one-third octave (12%). It is constant percentage bandwidth and is a single pole pair configuration. The shape has skirts which asymptote to 6dB. See Fig 2.8.1. To change the filter bandwidths from about one octave (100%) to sharper than one tenth octave (<1%) see section 4.

When using the narrow band mode, both the INPUT and DISTORTION gain controls are effective. The absolute signal level (at the filter frequency center) is the meter reading plus the INPUT control selection plus the DISTORTION control selection with the following notation. In this mode (as in the DISTORTION mode) the INPUT control has no greater sensitivity than -20dB. That is, the -30, -40, -50 and -60 positions give the same effect as -20. Therefore to measure low level signals first turn the INPUT control to -20 and then the DISTORTION control to the position that gives an on-scale meter reading. For example, if the meter reading is -4.5dBV, the INPUT control is at -20 and the DISTORTION control at -70, the actual absolute signal level is:

Signal level (dBV) = 4.5 + (-20) + (-70) = -94.5dBV

The 3501 can also be configured to be a low pass filter. This is achieved by pushing the first and third FUNCTION buttons. In this mode the corner frequency is set by the FREQUENCY controls. The filter has a 12dB per octave rolloff. See Fig 2.8.2. Level measurement is the same as the BAND PASS mode.

The low pass configuration is particularly useful for noise measurements in a specific bandwidth. For example, to measure the noise in a flat spectrum to say 20kHz just tune the FREQUENCY control to that frequency and proceed as above.

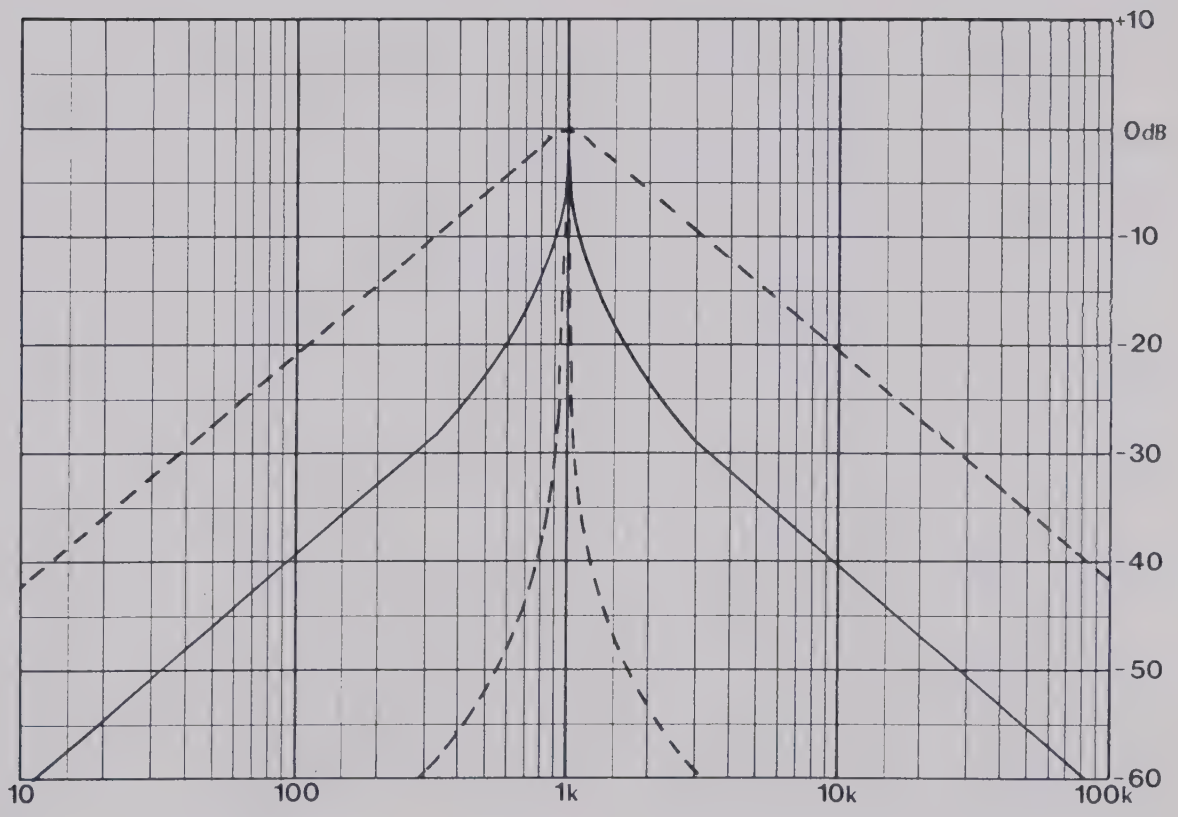


FIGURE 2.17 BAND PASS RESPONSE

Frequency response of the tunable filter selected by the BAND PASS mode. The filter is shown plotted with a 1kHz center frequency but may be tuned from 10Hz to 100kHz with the same percentage bandwidth or Q. The wide response shown is the lowest Q available; the narrow response the highest Q (about 1% or a Q of 100). The middle response is approximately 12% (Q of 8.3) and is the response of the filter at factory shipment. See Section 4 for details of alternate bandwidth settings.

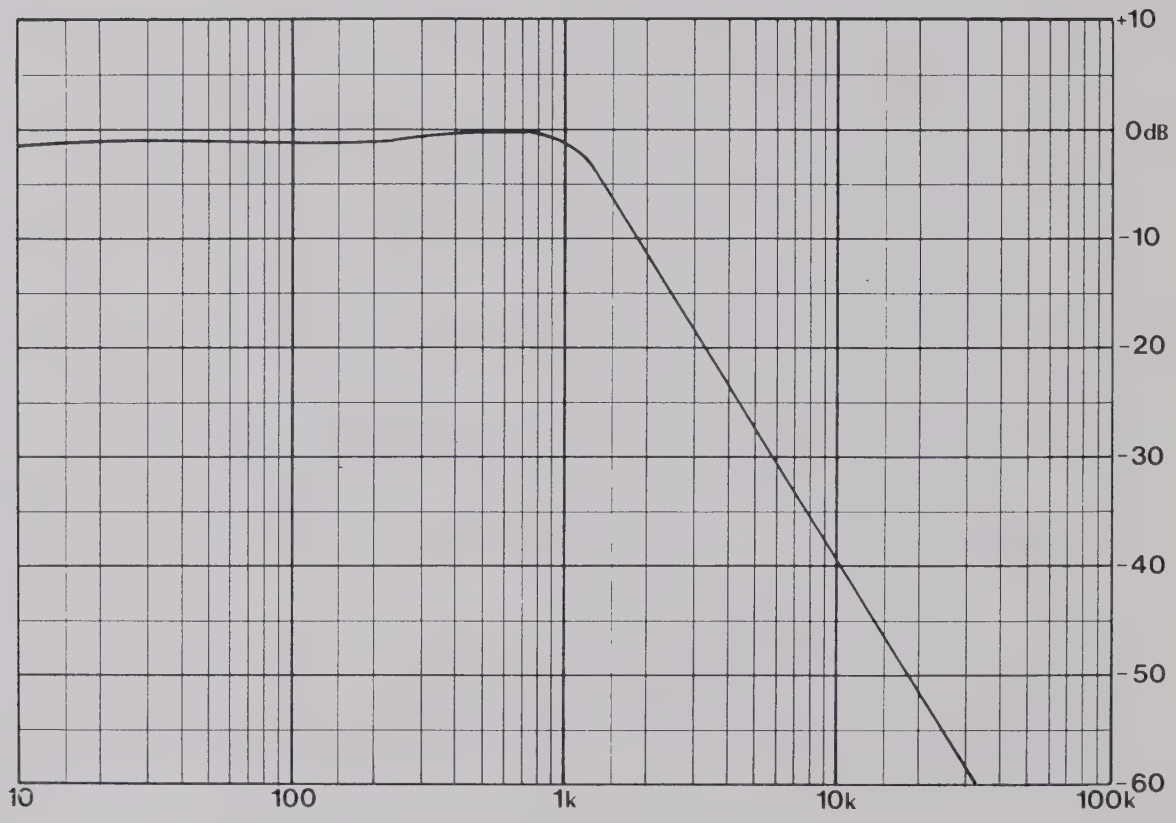


FIGURE 2.18 LOW PASS RESPONSE

Frequency response of the tunable filter selected by the LOW PASS mode. The filter is shown plotted with a 1kHz corner (-3dB) frequency but may be tuned from 10Hz to 100kHz and retain the same shape. The filter is a 2-pole network giving a 12dB per octave roll-off. Pass band ripple is 3dB maximum; 2dB typical.

This filter may be used for specified bandwidth signal-to-noise measurements. For example, it may be set to 20kHz for a "Audio Bandwidth" measurement.

2.9 dB RELATIVE MEASUREMENTS

This front panel rotary control can offset the meter readings by up to + or −12dB. Using this control a given level reading can be adjusted to "0dB" so subsequent readings will be in dB, relative to this first one. This control can be used in any mode although in general it will only be used in the LEVEL mode.

For example, to measure frequency response "relative to 1kHz":

a) Set the generator to 1kHz.
b) Select LEVEL and make an on-scale reading as described in 2.5 previously.
c) Adjust the meter pointer to 0dBV or 0dBm using the dB relative control.
d) Readjust the FREQUENCY control to other frequencies and note the variation in dB relative to 1kHz.

Note that an "UNCAL" red LED will be lit in the meter scale area when the dB relative feature is being used as a reminder to return it to the detented off position after use.

2.9.1 SIGNAL TO NOISE MEASUREMENTS

Signal to noise measurements are used to qualify the noise performance of a device under test. They are expressed as a dB figure relating noise floor to normal signal level -- the larger the number, the lower the noise floor and hence the better the performance.

Signal to Noise Measurements (S/N) can be easily made using the 3501. First, it is necessary to establish the signal reference point. This is based on tradition, manufacturers' choice, a particular standard or other source. For amplifiers it is usually the full power level or clipping point. For processing equipment it is usually the operating level or program level (possibly 10 or more dB below clipping). For tape recorders it is the level that produces a particular amount of distortion, perhaps 3% or 1%. Consult the manual for the device under test or the standard to determine the Reference Signal Level.

The second factor is the measurement bandwidth and any possible bandwidth weighting. These factors can have a very significant effect on the measured figure and it is essential to use the specified procedure. For example, tape recorders are usually measured using ANSI/IEC "A" weighting. Amplifiers and signal paths are often measured using a flat "program weighted" or "audio" bandwidth of 20Hz to 20kHz. Virtually all standard weighting characteristics can be produced by a 3501. Some may require the addition of an accessory in the form of a plug-in network. For example, "A" weighting can be provided as a simple module; "audio" bandwidth by the low pass configuration described in Section 2.8.

Having established the proper reference signal level and weighting we can now proceed to the S/N ratio measurement.

Step 1:

With the weighting (Filters) not selected establish the correct Reference Signal Level at the output of the device under test. This may require a Distortion measurement, Wattage measurement or other condition.

Step 2:

With the 3501 in the LEVEL mode, reading this Reference Signal Level, adjust the dB RELATIVE control to obtain a 0dBV (or 0dBm) meter reading.

Step 3:

Turn off the GENERATOR of the 3501 using the OUTPUT ATTENUATOR. Select the appropriate WEIGHTING filter, if required.

Step 4:

Select the LOW PASS function by pushing the first and third FUNCTION buttons. Turn the FREQUENCY control to set the upper cutoff frequency – usually 100kHz or 20kHz.

Step 5:

Turn the DISTORTION control to obtain an on-scale meter reading (without changing the previously set dB relative control).

Step 6:

Add the meter reading on the dBV (or dBm) scale to the dB value on the DISTORTION control to obtain the correct signal-to-noise value.

For example, suppose the Reference Signal Level is established to be +8dBm. The INPUT control is set to +10dB/3V, LEVEL is selected and a meter reading of -2dBm is noted. This reading is changed using the dB relative control to 0dBV, the OUTPUT LEVEL attenuator set to OFF and the required weighting selected. The FREQUENCY is set to perhaps 20kHz and the LOW PASS mode selected. The DISTORTION control is turned until an on-scale meter reading is obtained. If this happens at say -70dB and shows a meter reading of say -4.5dBV, the correct signal-to-noise ratio is -74.5dB.

2.10 MONITOR OUTPUTS

These front panel outputs provide a signal for external observation. They will normally be connected to an external oscilloscope but can also be connected to an external low frequency spectrum analyser to improve the distortion measurement resolution.

2.10.1 INPUT MONITOR

This output is a scaled representation of the INPUT signal. It is after the input attenuator and presents a signal for an external oscilloscope for fundamental monitoring, trigger purposes, external counter, etc. The output signal level is approximately -10dBV or 300mV for full scale readings in the LEVEL mode and DISTORTION control settings of -80dB/0.01% or lower. For DISTORTION control settings of -70dB/0.03% or higher the signal is 10dB lower (i.e. -20dBV or 100mV). Output source impedance is approximately 600 ohms.

2.10.2 DISTORTION MONITOR

This output is a scaled representation of whatever the meter is indicating. In the LEVEL mode, it is the signal being measured. In DISTORTION it is the distortion residual products. In the NARROW BAND mode (BAND PASS and LOW PASS) it is the filter output. The signal levels are the same as the INPUT monitor described above.

2.11 POWER SUPPLY

The enclosure of the 3501 contains the regulated power supply and optional battery and charger.

This supply operates from a nominal 14V AC and produces the two isolated bipolar supply rails required by the instrument. ($\pm$15V for the measurement circuits and $\pm$20V for the generator circuits). It contains a high efficiency switching type inverter using state of the art techniques such as VMOS transistors and operates outside the measurement bandwidth (approx. 600kHz) to avoid interference.

An external mains transformer is supplied to provide the nominal 14V AC to the power input connector. Alternatively, a DC source could be provided to power the instrument. The voltage of this DC source should be 10 to 16V for instrument operation and 18 to 20V for internal battery charging. This source may be provided at either polarity. See section 4 for pin connections.

2.12 OPTIONAL RECHARGEABLE BATTERY

If this option is supplied, an internal rechargeable battery is provided in addition to the above described power supply.

The supply also includes a battery charging circuit and battery voltage detector circuit. During operation from

the battery (or external power source) the 3501 will automatically switch off when the battery (or external source) falls below approximately 9 Volts. This will avoid total discharge of, and consequent damage to, the battery.

A BATTERY TEST push button switch is located on the front panel. This uses the front panel meter to indicate battery voltage. Mid-scale corresponds to approximately 8V and is indicated by a reading of -4dBV or 2 on the Volts/% scale. A fully charged battery will indicate approximately +1dBV or 3.5 on the V/% scale under load (i.e. 3501 operating). (With no battery installed, BATTERY TEST will indicate the internal power supply voltage.)

The red POWER ON LED will indicate when the battery life is in the last 10 percent of its range. It will flash at a rate indicating the remaining time starting at a slow rate when about 90% of the battery is consumed and increasing until automatic shut-off.

2.12.1 BATTERY CHARGING CONDITIONS

To charge the battery, connect the external mains transformer (or a user supplied source of 14V AC or 18V DC) to the 3501 power input connector. The battery will charge in 6 to 12 hours with this source and the instrument turned off. It will not charge with the instrument turned on (nor will the battery be discharged). During this charge period, the front panel CHRG LED will light. At the completion of charge, the charger will automatically revert to a float mode and the LED will be extinguished. It can remain in this mode indefinitely.

Do not allow a discharged battery to sit for an extended period (more than a few days) prior to recharging.

2.12.2 BATTERY DISCHARGE CONDITIONS

With option 001, a fully charged battery should give between one and two hours of continuous use before automatic shut off. If it is not used continuously, the total discharge time can be extended beyond this time. Option 002 gives approximately twice this discharge time.

If the instrument is allowed to run until shut off, then left to sit for several hours, it should be possible to obtain additional time before recharging. However, if possible, avoid this procedure as this deep discharge operation will shorten battery cycle life.

Under proper conditions, a single battery will give 300 to 500 or more charge/discharge cycles. Good battery care includes recharging as soon as possible after discharge and avoiding deep discharge

conditions (repeated deep discharge prior to recharge).

2.12.3 INTERNATIONAL VOLTAGE OPERATION

For international AC mains operation, the 003 option is provided. This is a transformer box that provides 14 VAC and a cable with the required power connector for the 3501. For mains connection, a power cord with an IEC mains connector on one end is provided to mate with an IEC mains receptacle on the 003. This connector also contains a means of setting the mains voltage to 100V, 120V, 220V or 240V to accommodate various mains conditions. It will operate from 48 to 62Hz without change. A mains fuse is also included.

2.13 IMD Distortion Measurement (OPTIONAL)

Option 006 adds IMD measurement and generation capability. Internal changes include the addition of a second oscillator and the IMD measurement circuits. These additional facilities share the input, output, monitors and metering functions of the basic instrument.

2.13.1 SMPTE/CCIF SELECTOR

The front panel function switch selects one of two IMD modes: SMPTE or CCIF. Select SMPTE by simply pushing the third FUNCTION button labelled IMD. Select CCIF by pushing the second and third buttons simultaneously.

The SMPTE mode involves the use of two sine waves, one a low frequency of 60Hz and the second a high frequency (7kHz for the normal SMPTE specification) mixed in a 4-to-1 amplitude ratio. The CCIF mode involves the use of two high frequency signals with a small frequency separation, for example 10kHz and 10.5kHz.

2.13.2 SMPTE IMD

The 3501 generates the SMPTE type of signal by adding a 60Hz LF sine wave to the existing variable frequency oscillator with the LF amplitude being 12dB higher than the HF. The frequency of the HF signal is set by tuning the front panel FREQUENCY control. Any frequency in the range from 2kHz to 100kHz may be used including, of course, the 7kHz SMPTE standard. The amplitude of this composite signal is internally calibrated to have the same peak amplitude as the equivalent THD sine wave signal. This peak calibration will ensure no clipping at high signal levels but will show a different RMS value on the LEVEL meter.

Measurement of the distortion of the LF + HF signal is identical to the THD measurement described in Section 2.6 of this manual. The INPUT and DISTORTION controls are set as in THD and the INPUT and DISTORTION MONITOR connectors provide oscilloscope outputs. The FILTERS should not be used in the IMD mode. The Low Pass filters are redundant and will show no significant change. The 400Hz High Pass filter would

incorrectly eliminate the distortion components which may apppear at 60Hz, 120Hz, etc.

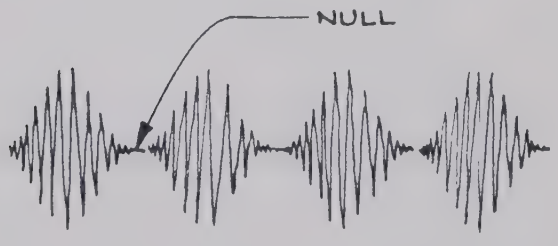
To repeat: use the instrument in the same way as THD but be sure the FREQUENCY is above 2kHz and don't use the filters.

2.13.3 CCIF IMD

The 3501 does not generate the complete CCIF test signal alone. This requires the use of two oscillators mixed for a 1-to-1 amplitude mix. The test signals should have a minimum value of 2kHz and a maximum frequency separation of 1kHz.

To generate the CCIF composite test signal, connect an external oscillator to the rear panel auxiliary input. The source should be adjustable in amplitude and have a nominal amplitude of approximately +12dBm (3V rms) when connected to the 600 ohm load presented by the auxiliary input.

It should have a frequency range of 2kHz to 100kHz. It need not have a low harmonic distortion but should have low hum content.



Look at the composite waveform at the OUTPUT on an oscilloscope. Adjust the amplitude of the external oscillator to just produce a null in the waveform.

This sets the two oscillators (internal and external) to a 1 to 1 amplitude ratio. Note that the peak amplitude of the composite signal is 6dB higher than the single THD signal. This limits the maximum setting of the OUTPUT level control before clipping will occur in the power amplifier. Be careful not to clip the output during measurement - no damage will result but serious errors will occur.

The 3501, when switched to CCIF, will measure the difference frequency component and express this amplitude as a percentage of the RMS sum of the two HF signals. It is somewhat equivalent to a highly sensitive voltmeter with a 1kHz low pass filter at the input. As above, do not use the FILTERS in this mode.

AMBER MODEL 3501

DISTORTION and NOISE

MEASURING SET

Issue 02

August 1982

OWNER'S MANUAL

SECTION 4

MODIFICATIONS & CUSTOM NETWORKS

4. MODIFICATIONS & CUSTOM NETWORKS

4.0 INTRODUCTION

The 3501 has some provision for user modification for particular applications. Most of these changes must be done by a qualified technician and it is assumed care will be exercised. Before proceeding with this section, refer to Section 6 and read the cautions regarding static sensitive devices and the 3501 disassembly procedure.

4.1 BAND PASS FILTER "Q" ADJUSTMENT

The 3501 may be configured as a frequency selective voltmeter by selecting the BAND PASS mode. This is done by pushing the first two FUNCTION buttons.

The BAND PASS mode inserts a variable frequency active band pass filter in the level measurement circuit. The filter is a State Variable type and is constant percentage bandwidth. This means the shape of the filter plotted on a log frequency axis will remain the same at any frequency.

The instrument is normally shipped with the filter set to a bandwidth of approximately 12%. This translates to a Q of 8.3 and means the filter will have -3 dB points separated by 120Hz when the center frequency is 1kHz.

By changing the value of one resistor the bandwidth of the filter may be varied over a range of approximately 100% to less than 1%. The filter has been configured so that as the bandwidth is changed the pass band gain (gain at the center frequency) will remain essentially constant at unity. In fact, within the filter itself lower bandwidths (higher Q) mean higher filter gain. At 1%, the effective internal filter gain exceeds 40dB although the actual instrument pass band gain is approximately -3dB. (At higher Q values, the center frequency gain suffers a slight attenuation.) This additional gain means a higher equivalent input noise when in the BAND PASS mode. It is equivalent to additional gain in the preamp as selected by the INPUT control. This noise will appear on the DISTORTION MONITOR output and may look like oscillation. It is in fact front end noise filtered by a sharp band pass filter and will therefore exhibit noise predominantly at the setting of the FREQUENCY control.

Note that the filter retains the automatic tuning capability of the notch configuration used in the THD mode. Thus, it will try to lock on to an incoming signal within its $\pm$10% capture range. This will simplify most measurements and relieve the difficulty of trying to manually tune an extremely sharp filter. However, it will also mean it is almost impossible to plot the frequency response of the filter since it will try to automatically track an incoming sweep. See the details on SERVO INHIBIT below if it is desired to suppress this automatic tuning.

4.1.1 FILTER Q MODIFICATION

Resistor R2045 located on the top (FILTER/OSCILLATOR) board is the one to be changed to effect modification of Q. Its effective value is that of this resistor in series with the R_{ds} ON of FET Q2077. As shipped, its value is 620 ohms resulting in a bandwidth of approximately 12%. The resistor may take values of infinity to zero ohms resulting in bandwidths of 100% to less than 1%. See Figure 4.1 for frequency response plots of various bandwidths. For sharper bandwidths (higher Q) the resistor must be decreased. The safest way to do this is to solder a resistor in parallel with the existing 620 ohm part. If the resistor must be removed, use caution to avoid damaging the circuit board.

A pot may be used to provide an adjustable bandwidth. For best results, use a 10k ohm reverse log taper. It may be mounted on the front panel to the left of the meter.

4.2 FILTER SERVO INHIBIT

The state variable filter used in the THD measurement section and the BAND PASS and LOW PASS modes has an automatic frequency tuning adjustment. This is one of the two servos used to automatically null the notch filter in THD. This frequency adjust servo will automatically tune the filter if a single input signal is within ±10% of the manual FREQUENCY setting.

There may be some applications where this automatic tuning is undesirable. For example, in the BAND PASS mode if it is desired to set the center frequency of the filter with the FREQUENCY knob and not have it drift to a nearby frequency trying to lock on to an input signal. To achieve this, the servo may be disabled to cause the filter to find its mean (panel dial) value. Of course, the servo must be enabled again in the THD mode or nulling will not take place.

To disable the frequency tuning servo, short out capacitor C2019 or short PIN 2 to Pin 6 of U2016. This may be done with a switch but the leads to the switch must be short (less than 10 inches). A switch could be mounted on the front panel to the left of the meter.

4.3 IMD LOW FREQUENCY CHANGE

If option 006 is provided, a second low frequency oscillator is contained on the option circuit board located on the bottom chassis. The frequency of this oscillator is nominally set to 60Hz but can be changed over the range of approximately 10Hz to 500Hz.

Two resistor values must be changed to set a new frequency. These resistors are R604 and R605 on assembly 3501-460-02. They follow the relationship:

$$\text{FREQUENCY} = \frac{10^6}{1.38R}$$

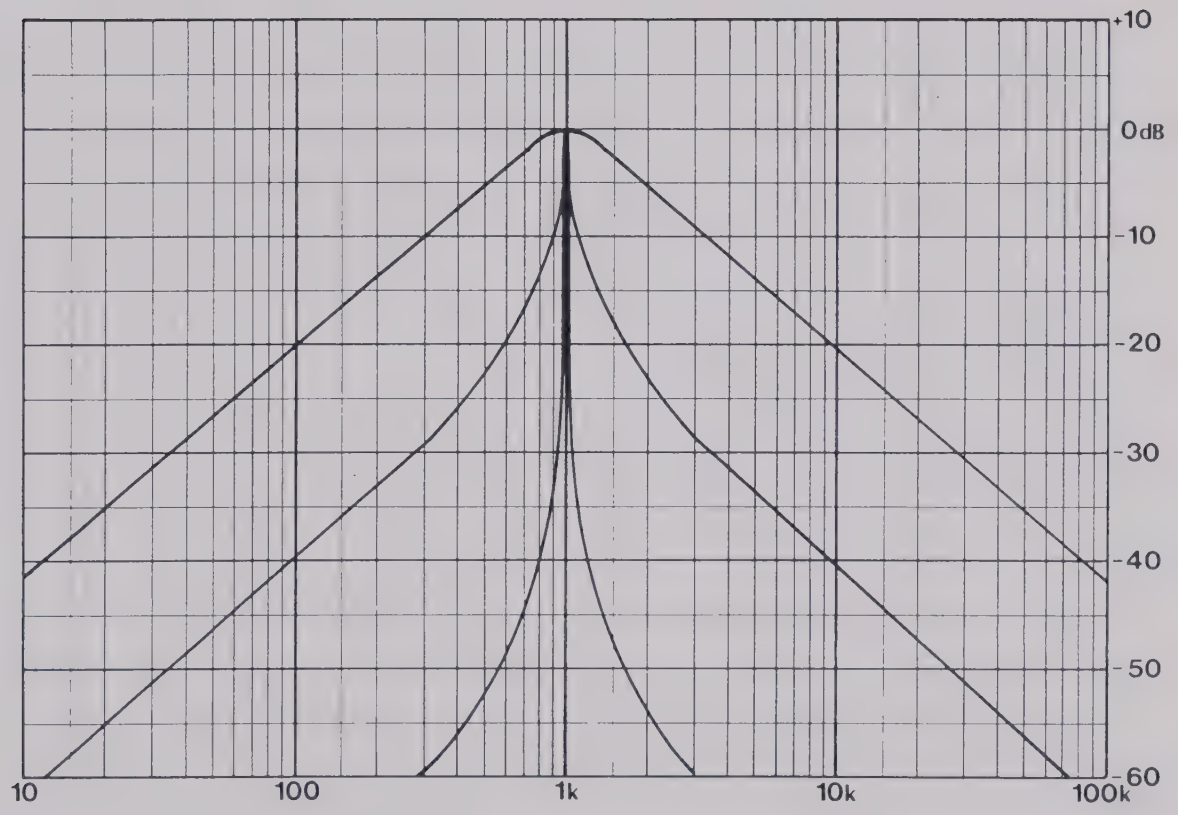


FIGURE 4.3 BAND PASS FILTER

Shown are typical frequency responses of the BAND PASS filter for various values of R2045. The widest response is a Q of 1 or percentage bandwidth of 100% with a resistor value of infinity (no resistor installed). The center response is a Q of 8.3, bandwidth of 12% and resistor of 620 ohms. This is the standard response shipped from the factory. The narrowest response is a Q of 100 or more, bandwidth of 1% or less and is obtained with a resistor value of 0 ohms (plus inherent resistance of FET).

As shipped, they are 12.2k ohm giving a frequency of 60Hz. For 10Hz use 71.5k and for 500Hz use 1.43k ohm. A dual ganged 50k ohm pot may be used to provide a variable frequency. There is provision for a four pin connector, J601, to handle an external control.

4.4 NOISE WEIGHTING FILTERS

The 3501 has provision for up to four noise weighting filter networks. Three are provided as standard and the fourth position is available for optional filters. This section contains details on how to construct filter networks to be used for noise weighting in the 3501. Note that all four filter positions may be installed in any position. The only caution is to observe the pin number orientation during installation.

4.4.1 GENERAL

Amplitude or Level measurements are generally made with a wide-band level meter which treats all signals in the frequency band of interest with equal weighting. That is, the frequency response of the meter is essentially flat over the measurement band. There are occasions, however, where it is desirable to restrict the bandwidth of the measuring circuits. Two common reasons are to reject noise or other unwanted signals and to better tailor the measurement to the subjective response of the human ear.

Examples would be: measurement of a signal in the presence of hum, reduction of measurement bandwidth from say 1MHz to 20kHz, removal of a noise component from a distortion + noise measurement and measurement of noise performance to some international weighted standard. This latter example results from the response of the human ear. At low sound pressure levels, the ear (or more correctly, the subjective realization of sound) is less sensitive to low and high frequencies. Noise in an electronic system is usually at a low level compared to signal. Thus, the ear would be less sensitive to a low or high frequency low level noise than a low or high frequency high level signal. Weighting curves approximating the ear's response have been developed. They are specified in standards available from ANSI, IEC and others. (See "A" Weighting following.)

Bandwidth restriction is very necessary for proper noise measurements. For "flat" noise (white noise) the noise level is proportional to the square root of bandwidth. Therefore, a preamplifier, for example, with a reasonably flat noise spectrum (not dominated by hum, crosstalk, etc) will exhibit vastly different noise performance when measured with a wide band AC voltmeter with a 1MHz bandwidth versus a voltmeter with a 20kHz bandwidth. It is therefore imperative that measurement bandwidth be specified with noise figures. It is equally imperative that the correct bandwidth or weighting be used

in the measuring instrument when readings are to be repeated with consistency. If a manufacturer specifies the noise of his amplifier in a 20kHz bandwidth the user must use this bandwidth to verify proper performance.

4.4.2 CONSTRUCTION OF CUSTOM NETWORKS

Several types of standard filters are described here along with details of how to determine component values to provide specific parameters. In addition to the networks presented here several others may be derived using classic filter design technique and implemented in a similar fashion. The configuration of the filter sockets, dedicated op amp and terminations provide near ideal filter conditions: low source impedance, extremely high op amp input impedance and wide op amp bandwidth.

For best results resistors should be 1/4 watt metal film with $\pm$1% tolerance, capacitors should be ceramic, plastic film or mica with $\pm$5% or better tolerance.

4.4.2.1 3rd Order Butterworth HIGH PASS and LOW PASS filter Networks

Three pole filters may be realized by using three resistors and three capacitors as shown in the instructions. The component location determines the filter character while its value, the -3dB point.

Capacitor values should lie between 200 pf and 0.5 uf while resistor values should be between 1k ohm and 500k ohm. Values for several frequencies are shown. Component values for other frequencies can be found by interpolation or extrapolation or using the 1Hz values and the following procedure:

LOW PASS

Divide the capacitor values shown by the desired -3dB frequency (fc). If the resulting capacitor values are too small multiply each by a constant and divide the 10k ohm resistor value by the same constant. If the capacitor values are too large divide each by a constant and multiply the 10k ohm resistor values by the same constant.

HIGH PASS

Divide the resistor values shown by the desired -3dB frequency (fc). If the resulting resistor values are too small multiply each by a constant and divide the 0.01 uf capacitor value by the same constant. If the resistor values are too large divide each by a constant and multiply the resistor values by the same constant.

EXAMPLE

Suppose we want a 60Hz high pass filter:

C1 = C2= C3= 0.01uf

R1 = 11.43 M ohm divided by 60 = 190.5K ohm

R2 = 78.63 M ohm divided by 60 = 1.310 M ohm

R3 = 4.49 M ohm divided by 60 = 74.83 K ohm

R2 is over 1M ohm and should be scaled to about 20% of this value. Choosing a standard value capacitor of 0.047 uf or 4.7 times the previous value we divide all resistors by 4.7 to arrive at the final values:

C1 = C2 = C3 = 0.047 uf

R1 = 190.5K divided by 4.7 = 40.5K ohm

R2 = 1.310M divided by 4.7 = 279K ohm

R3 = 74.83K divided by 4.7 = 15.9K ohm

Note: when soldering to the 16-pin dual-in-line headers, use caution not to melt the plastic. Install the header in a 16-pin socket clamped in a vise to hold the pins straight during soldering.

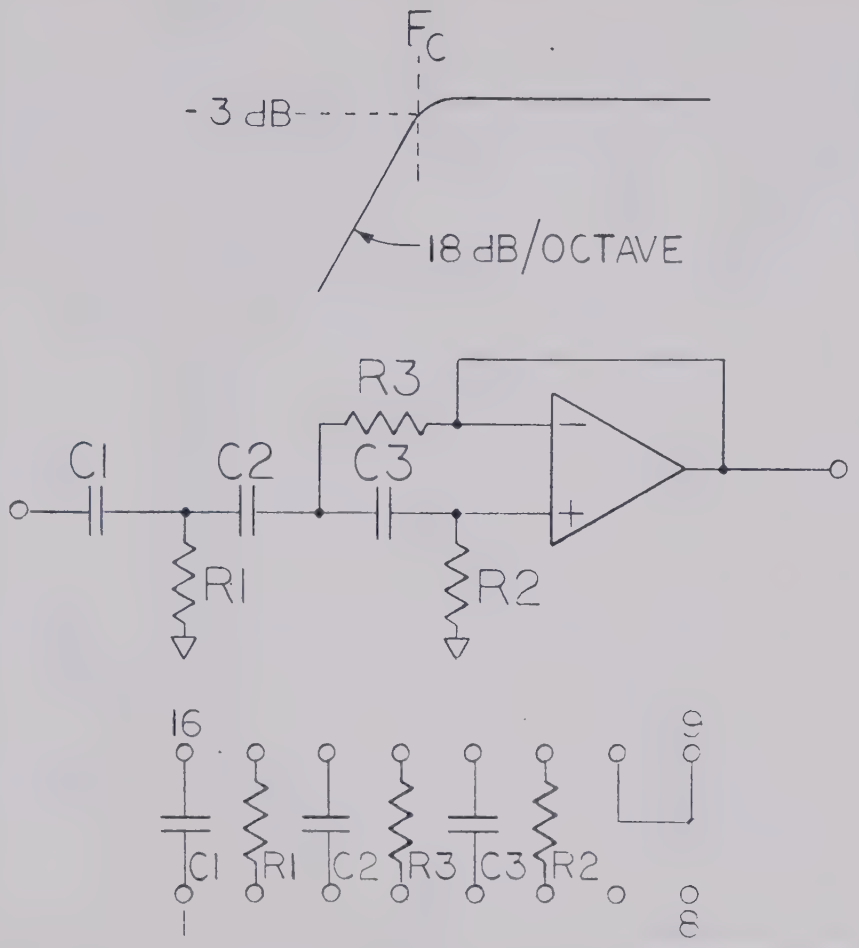
4.4.2.2 ANSI/IEC "A" WEIGHTING

Details are also provided for construction of networks to provide curves conforming to the ANSI/IEC "A" Weighting specification.

This curve conforms to ANSI specifications S1-4-1971 "Specifications for Sound Level Meters"; IEC Recommendation of Publication 123, First Edition 1961 "Recommendation for Sound Level Meters" and Publication 179 Second Edition 1973 "Precision Sound Level Meters".

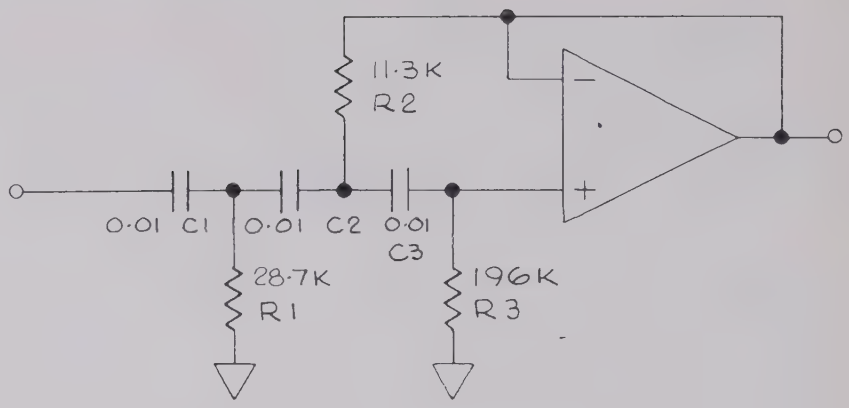
"A" Weighting is typically used for tape recorder signal-to-noise measurements and acoustic noise measurements.

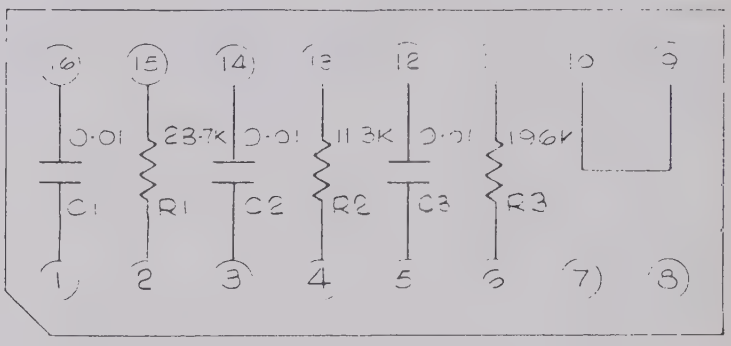
3 POLE HIGH PASS FILTER (BUTTERWORTH)

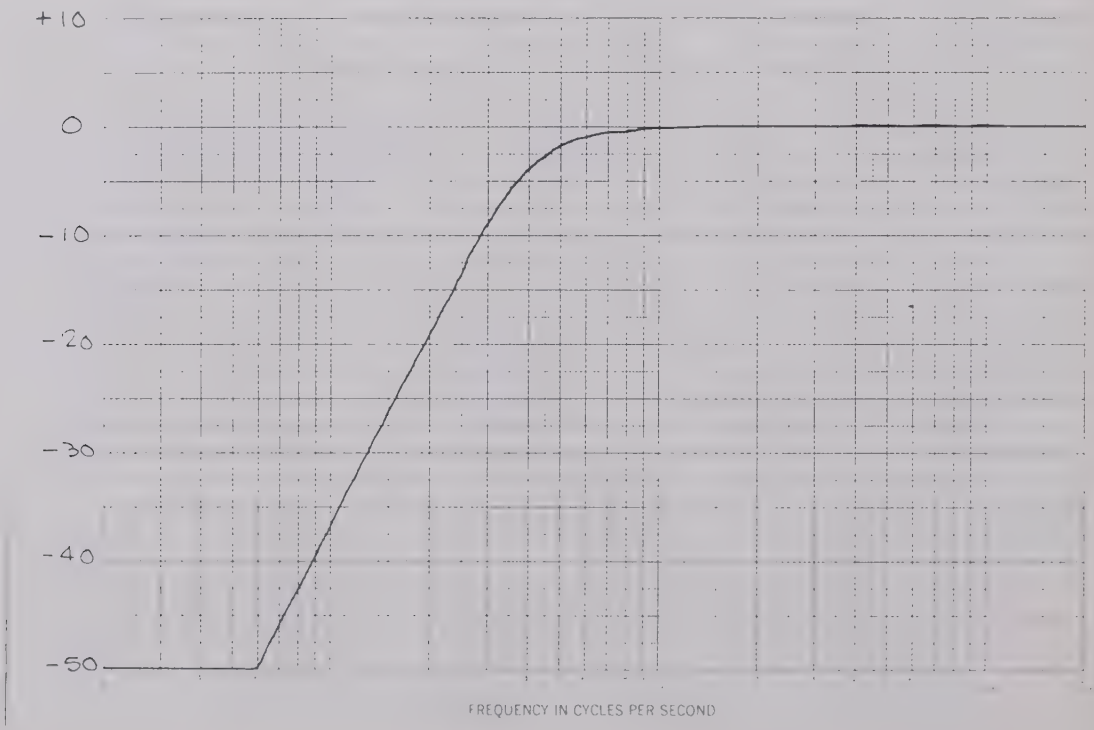


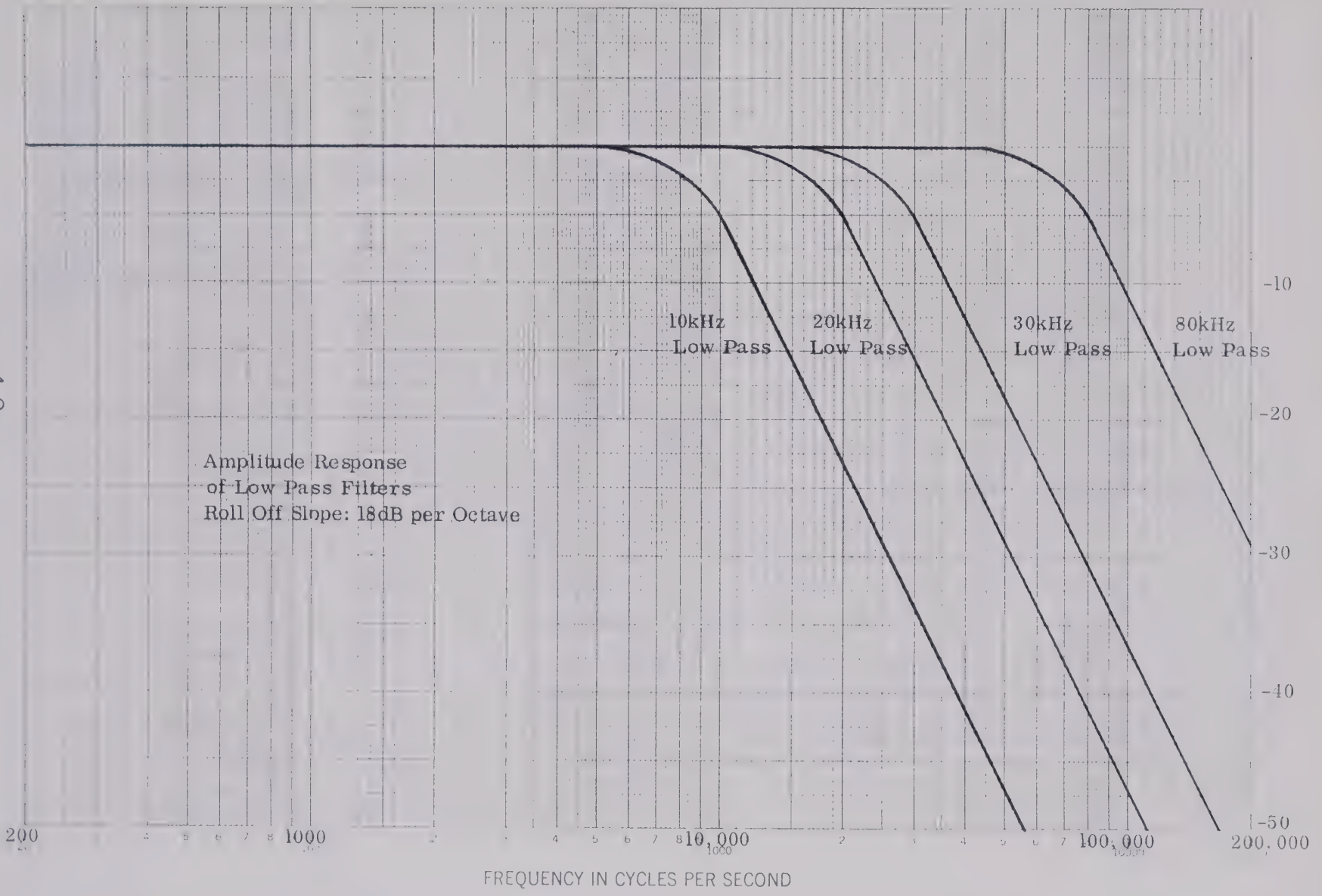
COMPONENT VALUES FOR HIGH PASS FILTER				
Fc	R_1	R_2	R_3	$C_1 = C_2 = C_3$
20 Hz	26.1 KΩ	178 KΩ	10.2 KΩ	0.22 uf
30 Hz	17.4 KΩ	118 KΩ	6.81 KΩ	0.22 uf
50 Hz	48.7 KΩ	332 KΩ	19.1 KΩ	0.047 uf
100 Hz	24.3 KΩ	169 KΩ	9.53 KΩ	0.047 uf
400 Hz	28.7 KΩ	196 KΩ	11.3 KΩ	0.01 uf
1kHz	22.6 KΩ	158 KΩ	8.87 KΩ	0.005 uf
10kHz	24.3 K	169 KΩ	9.53 KΩ	470 pf
1 Hz	11.43 MΩ	78.63 MΩ	4.49 MΩ	0.01 uf

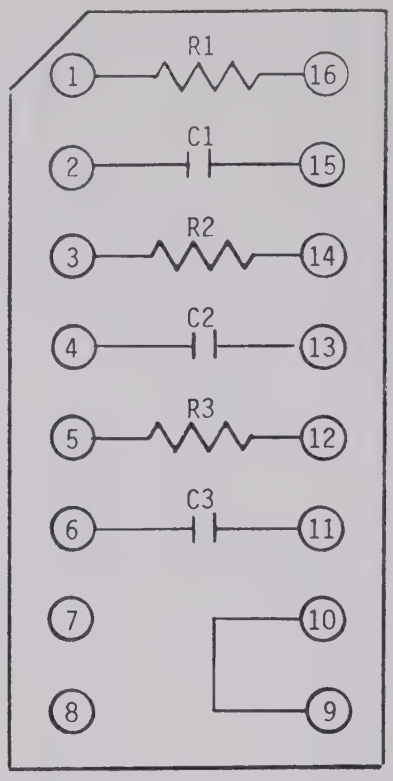
400 Hz
HIGH PASS
18dB/Octave








10kHz
Low Pass
20kHz
Low Pass
30kHz
Low Pass
80kHz
Low Pass
Amplitude Response
of Low Pass Filters
Roll Off Slope: 18dB per Octave
-10
-20
-30
-40
-50
200
1000
10,000
100,000
200,000
FREQUENCY IN CYCLES PER SECOND



	10kHz	20kHz	30kHz	50kHz	80kHz
R1	10k0	4k99	3k32	2k0	1k24
R2	10k0	4k99	3k32	2k0	1k24
R3	10k0	4k99	3k32	2k0	1k24
C1	←		2200pf		→
C2	←		5600pf		→
C3	←		330pf		→

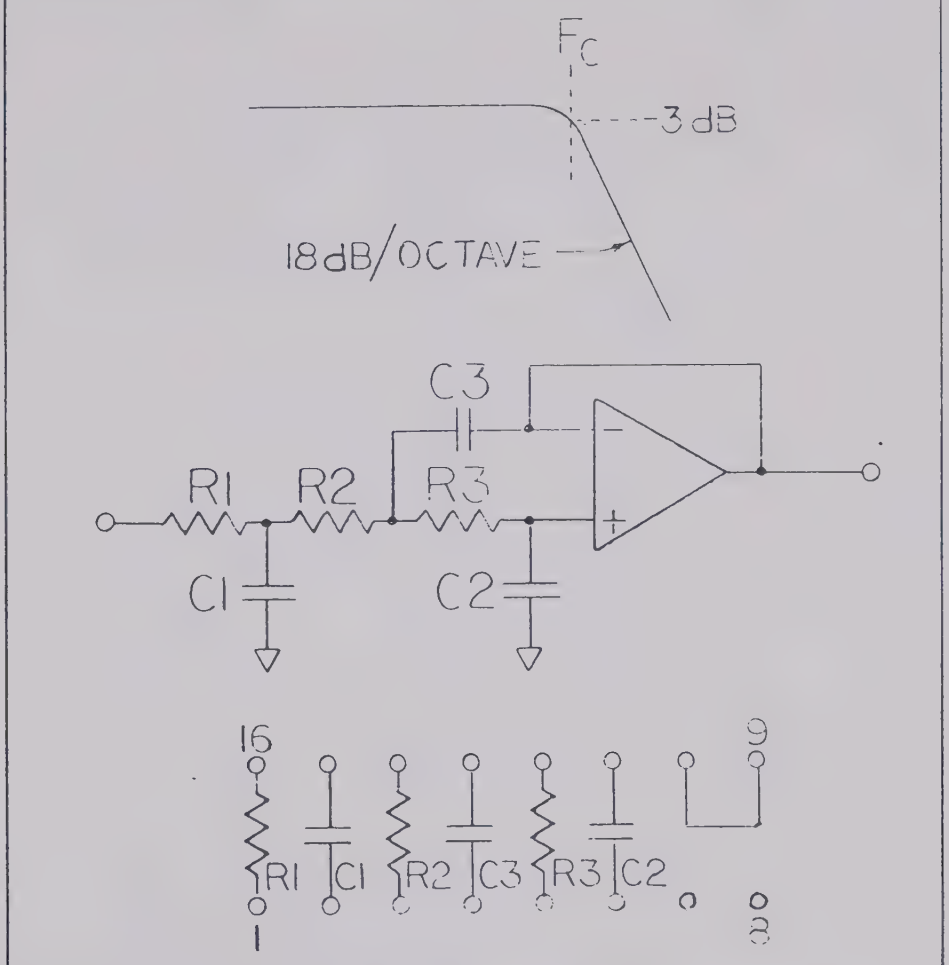
AMBER ELECTRO DESIGN LTD

3 POLE LOW PASS NETWORK

ISSUE 01 NOV 20/80

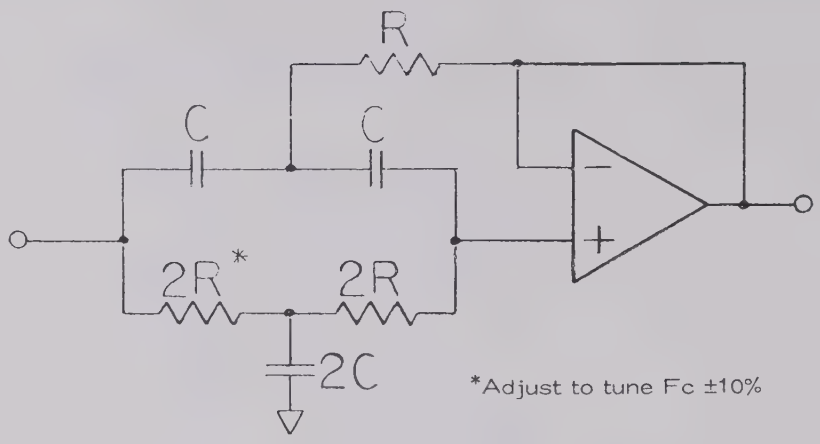
amber

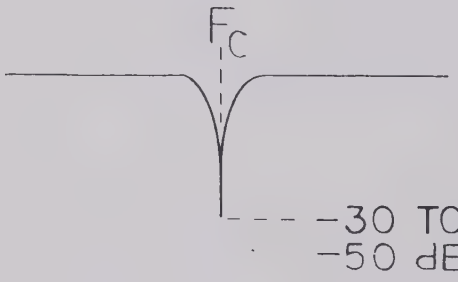
3 POLE LOW PASS FILTER (BUTTERWORTH)



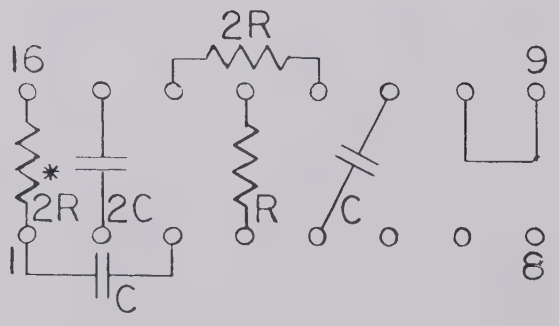
COMPONENT VALUES FOR LOW PASS FILTER				
Fc	C_1	C_2	C_3	$R_1 = R_2 = R_3$
100 Hz	0.047 uf	0.0068 uf	0.12 uf	47.5 KΩ
1kHz	0.022 uf	3300 pf	0.056 uf	10.0 KΩ
10kHz	2200 pf	330 pf	5600 pf	10.0 KΩ
20kHz	2200 pf	330 pf	5600 pf	4.99 KΩ
30kHz	2200 pf	330 pf	5600 pf	3.32 KΩ
50kHz	2200 pf	330 pf	5600 pf	2.00 KΩ
100kHz	2200 pf	330 pf	5600 pf	1.00 KΩ
1 Hz	22.15 uf	3.221 uf	56.44 uf	10 KΩ

2 POLE "TWIN TEE" BAND REJECT FILTER



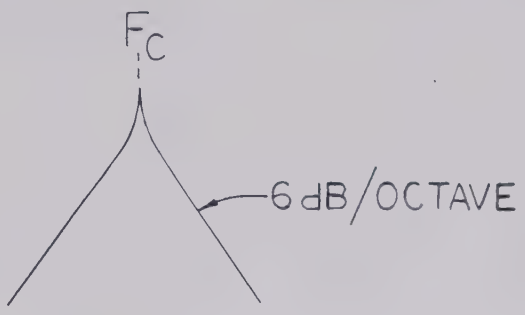


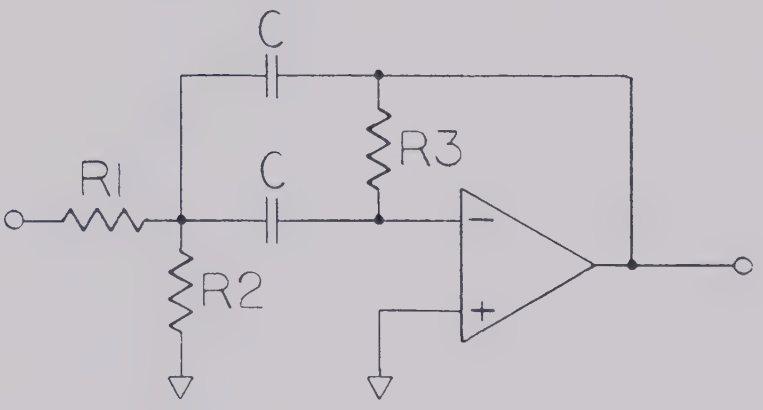
$$Fc = \frac{1}{4\pi RC}$$

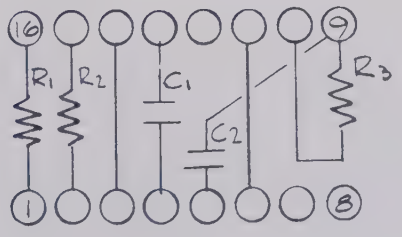


COMPONENT VALUES FOR BAND REJECT FILTER				
Fc	R	2R	C	2C
60 Hz	26.7 KΩ	53.6 KΩ	0.05 uf	0.1 uf
120 Hz	13.3 KΩ	26.7 KΩ	0.05 uf	0.1 uf
400 Hz	20.0 KΩ	39.2 KΩ	0.01 uf	0.02 uf
1kHz	15.8 KΩ	31.6 KΩ	0.005 uf	0.01 uf
10kHz	2.43 KΩ	4.87 KΩ	3300 pf	6800 pf

SINGLE POLE PAIR BANDPASS FILTER







For Gain at Fc = -1 $R_3 = 2R_1$

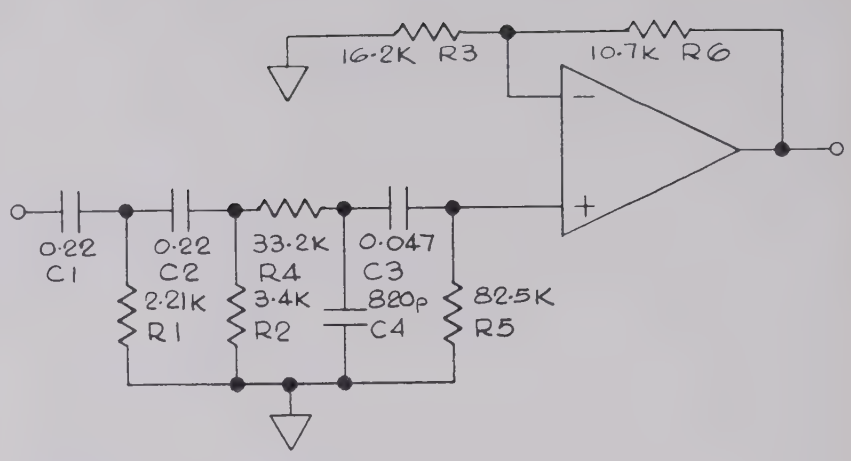
$$\text{Filter Q} = \frac{Fc\, R_3 C}{2}$$

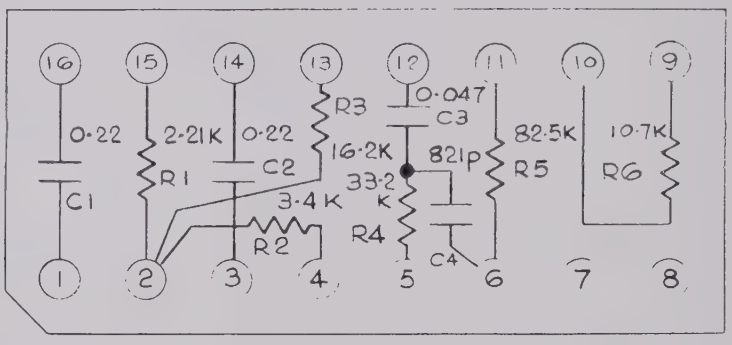
$$Fc = \frac{1}{\pi}\sqrt{\frac{R_1 + R_2}{2R_1^{\,2} C^2 R_2}}$$

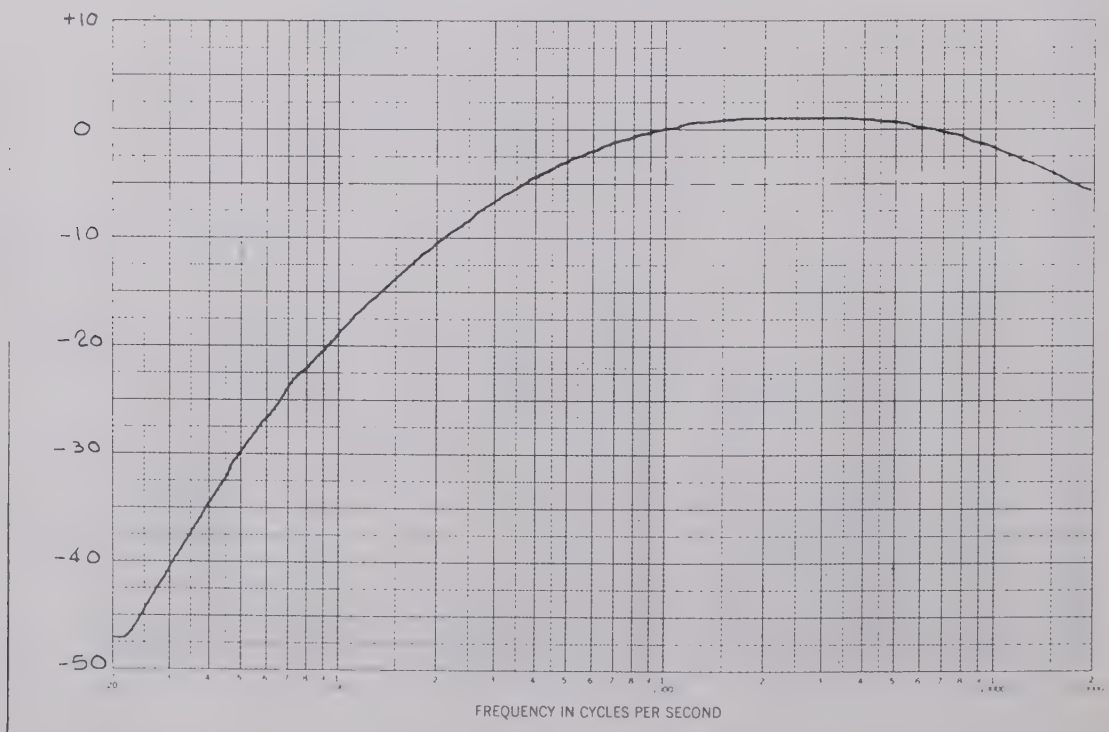
Example: For Q = 10
Fc = 1kHz

C = 0.1 µf
R_1 = 10KΩ
R_2 = 530Ω
R_3 = 200KΩ

ANSI-IEC
A
WEIGHTING







ANSI – IEC
B
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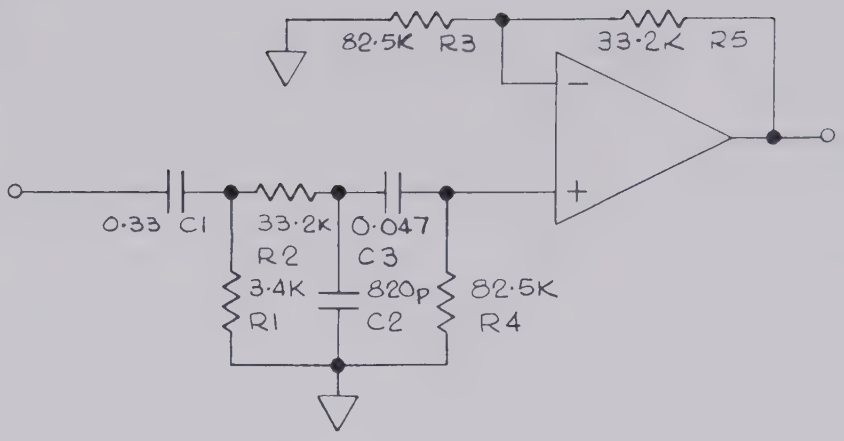

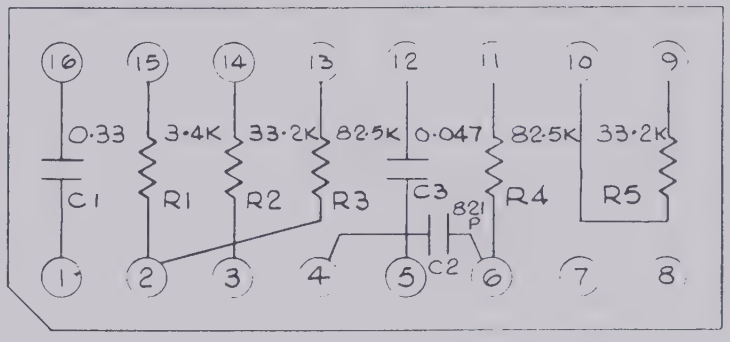

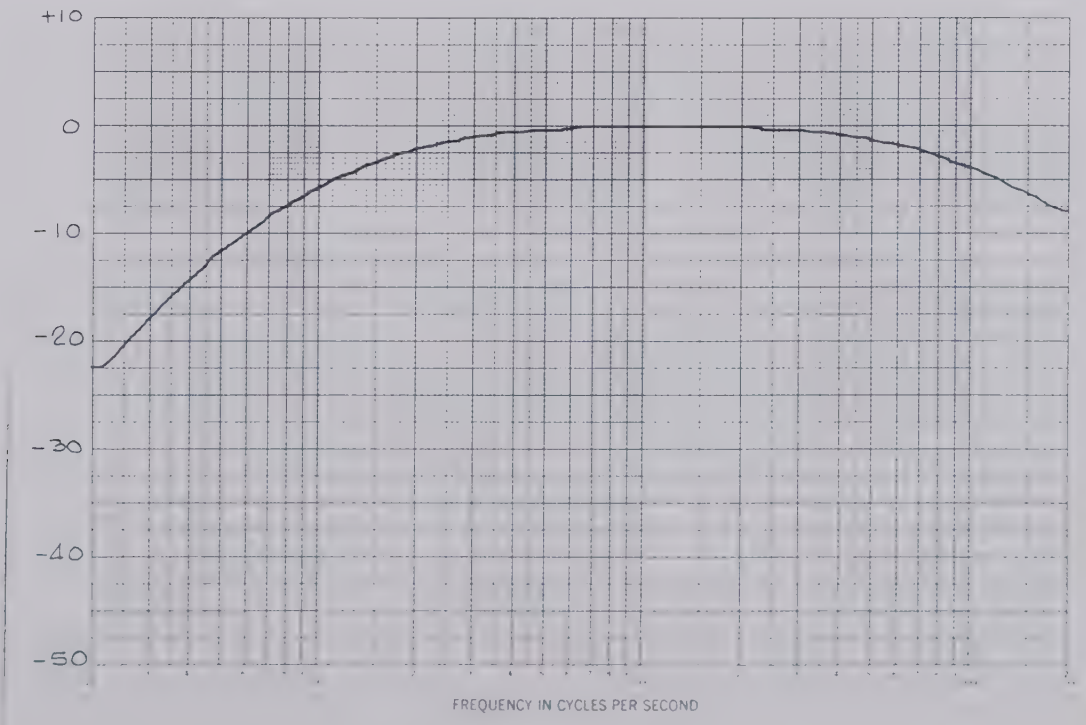

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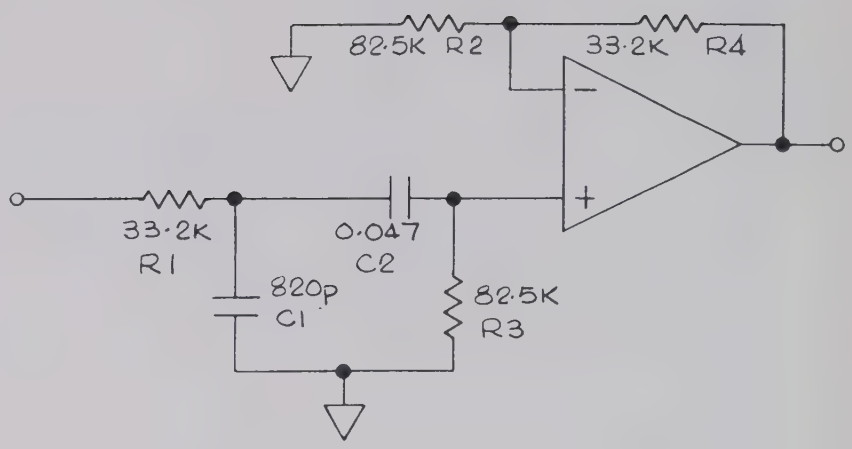
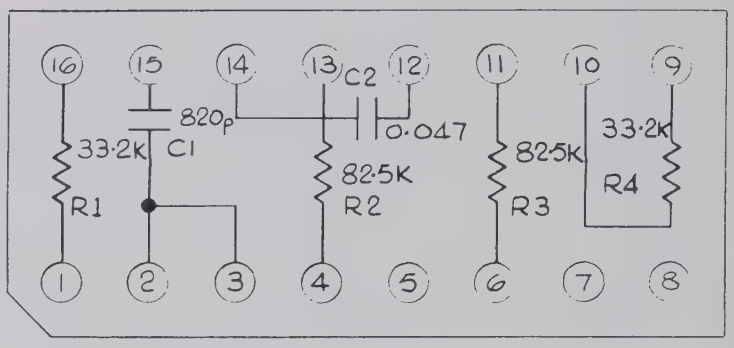
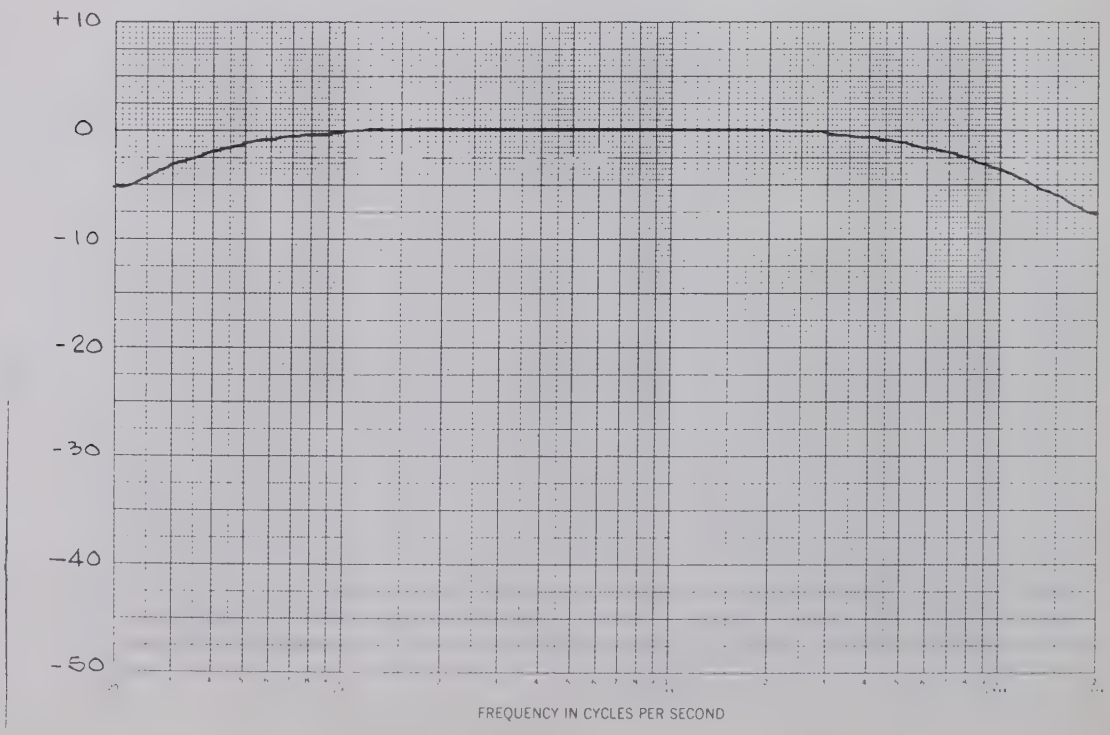






AMBER MODEL 3501

DISTORTION and NOISE

MEASURING SET

Issue 02

August 1982

OWNER'S MANUAL

SECTION 6

MAINTENANCE & CALIBRATION

CAUTION : This instrument contains CMOS and other types of semiconductors that are sensitive to electrostatic discharge. These parts can be permanently damaged or their reliability diminished unless proper handling procedures are followed.

Before removing the cover of this instrument, study these procedures carefully and follow them rigorously to avoid damaging your instrument.

1 – USE A STATIC FREE WORK STATION

This includes an antistatic work surface grounded via a high value resistor (330k ohm, for example) to a hard ground. Avoid all plastics, vinyl and styrofoam including styrofoam cups, plastic coffee cups, plastic coffee cup holders, cigarette packages with cellophane wrappers, plastic combs, vinyl books or folders, plastic covers on work sheets, plastic bottles, plastic bags, potato chip bags, plastic purses, plastic solder suckers and plastic ashtrays.

2 – ENSURE THAT YOUR BODY IS GROUNDED BEFORE TOUCHING ANY STATIC SENSITIVE DEVICE

Develop habits to prevent discharging your body into static sensitive devices. When approaching a test bench touch a ground first. When working on equipment wear a metallic wrist strap connected via a 330k ohm resistor to hard ground. If not wearing a grounding strap, hold on to a ground while touching any semiconductor (unpowered of course).

3 – KEEP PARTS AT GROUND POTENTIAL

Store parts in antistatic containers such as special antistatic integrated circuit storage tubes or special conductive foam. Pick up parts by the body of the item, not the leads. Do not subject semiconductors to sliding movements over any surface at any time.

4 – USE GROUNDED TEST EQUIPMENT

This includes soldering iron tips, voltmeters, oscilloscopes, etc. Never probe or test unpowered semiconductor circuitry circuitry with an ohm meter.

COMPONENT REMOVAL & REPLACEMENT

Components that are soldered in place must be removed with great care to avoid permanently damaging the printed circuit board. Amber circuit boards are among the highest quality available but, as with all boards with high component density, small somewhat fragile traces are used. Improper component removal could pull these traces off the board necessitating major repair.

To remove a defective or suspect component first remove solder from the mounting pad. Use a good quality vacuum solder removal tool or similar technique to remove solder from around and inside the plated through hole that mounts the component. After this is done, carefully free the leads one by one which will probably be sticking to one side of the hole. Use care to avoid damaging the pad. It is suggested that where possible, the component be crushed to allow each lead to be removed individually. If this is not possible cut each lead close to the component body, remove the body then the leads one by one. Do not use excessive force to pull the leads out of the board. They should either fall out by gravity or be able to be gently removed by applying a slight heat to the lead with a soldering iron. Avoid overheating the pad as this could destroy the adhesive holding the pad and trace to the board substrate. Examine each removed lead to see if the internal hole plating has been removed by accident. If so, this pad will have to be soldered to both sides of the board when the new component is inserted to maintain continuity.

Careful practice in component removal will prevent any board damage and leave the component mounting pads and surrounding board area in the same state it was in before component removal.

6. MAINTENANCE & CALIBRATION

6.1 CALIBRATION

The model 3501 contains a number of internal calibrations and adjustments. These fall into two categories: those requiring calibration to an external standard and those requiring adjustment for best performance. The former require the use of high precision calibration equipment not usually available in the average shop. A reasonable level of calibration, though below the 3501 specifications, can be done using a high quality AC level meter as the external reference.

All trim adjustments are located on the three or four circuit boards: Filter/Oscillator, Input/Meter, Power Supply and IMD. The three signal boards are located in the plane of the top or bottom cover while the power supply is located on the rear panel. The Filter/Oscillator board is on the top of the instrument, with adjustments accessible by removing the top cover. The Input/Meter board is located on the bottom with its adjustments accessible by removing the bottom cover. The IMD board, if provided, is also on the bottom. Note that it is only necessary to remove the top and/or bottom cover to gain access to most trim adjustments. An exception are the adjustments for common mode rejection on the optional plug-in preamp (balanced input option 004), if provided. To gain access to these trims, the bottom chassis holding the front panel OUTPUT switches and the optional IMD board must be tilted back. Refer to Section 6.6.1 for instrument disassembly before removing the chassis.

6.2 INPUT/METER BOARD (3501-410-02)

This circuit board contains seven trim adjustments which calibrate the accuracy of the 3501 meter. Two additional trim adjustments for common mode rejection are located on the optional plug-in pre-amp, if supplied (option 004).

6.2.1 LEVEL METER CALIBRATION

Equipment required: Precision AC calibrator such as Fluke model 5200A.

Alternative equipment: If a precision AC calibrator is not available, use an accurate AC level meter and the Generator of the 3501. The accuracy of the adjustment will then be only as good as the accuracy of the meter used and may produce some anomalous results.

Note that the mechanical "zero" of the meter is set to cause the pointer to rest just off the left end stop with no signal on the meter (3501 turned off). This is due to the fact that the meter law is logarithmic.

Connect the AC calibrator to the 3501 INPUT and select the LEVEL FUNCTION. Set the INPUT control to +10dB/3V and set the

distortion control to -70/0.03%. Adjust the AC calibrator to exactly 1.000V AC at some midband frequency, 1kHz preferred. Adjust R1128 so the meter points to -10dBV or 1 on the 3FS Volts/% scale (that is at the lower left end of the scale).

Turn the INPUT control to 0dB/1V and adjust VR-1122 so the meter points to 0dBV or 1V. Check the -10dBV reading with the INPUT control at +10dB again and if necessary iterate back and forth between the 0 and +10dB positions of the INPUT control and R-1128 and R-1122 to achieve the correct result.

With the INPUT control to 0dB/1V and the meter indicating a 0dBV/1V, turn the distortion control to -80/0.01% and adjust R-1127 for the same reading.

6.2.2 RADIOMETRIC CALIBRATION

Connect the AC calibrator as above and set the distortion control to -80/0.01% and select the test mode (FUNCTION select buttons all out).

Set INPUT control to 0dB (again using the 1.000V AC source). Adjust R-1130 for a 0dBV meter indication.

Set INPUT control to +10dB and adjust R-1055 for the same meter indication (0dBV).

Iterate the above steps if necessary to achieve a constant 0dBV meter reading as the INPUT control is switched between 0 and +10 with a constant input level of 1.000 Volt.

Set distortion control to -70/0.03%, adjust R-1117 for the same meter indication as the -80/0.01% position.

6.2.3 COMMON MODE REJECTION (if option 004 provided)

Connect a single ended AC source of 3.000V (+10dBV) to both balanced inputs of the 3501. To do this it will be necessary to connect to both the tip and ring of the three conductor phone jack BALANCED input. Set the INPUT control to +10dB and the DISTORTION control to -80/0.01%. Connect the INPUT MONITOR output to an oscilloscope and adjust R-319 for the most complete null. Change the source frequency to 50kHz and adjust C-306 trim-cap for the most complete null.

6.3.0 FILTER/OSCILLATOR BOARD

This circuit board contains thirteen trim adjustments. Eight are located on the right half of the board; this section is the oscillator. The five remaining are on the left half of the board; this section is the fundamental rejection/filter circuit. Because both oscillator and notch filter contain broad band second harmonic distortion trims, depending on the relative phase of distortions, reinforcements or cancellations may occur thus causing an erroneous calibration. Therefore the calibration of the oscillator requires a perfect analyzer and vice versa. However an alternative technique, described in the calibration steps, overcomes the cancellation/reinforcement effects described and makes the 3501 oscillator and analyzer distortion self-calibrating with a very high degree of accuracy. Before beginning the calibration steps, some terminology used in the description is explained which would aid in the interpretation of results.

FUNDAMENTAL REJECTION -

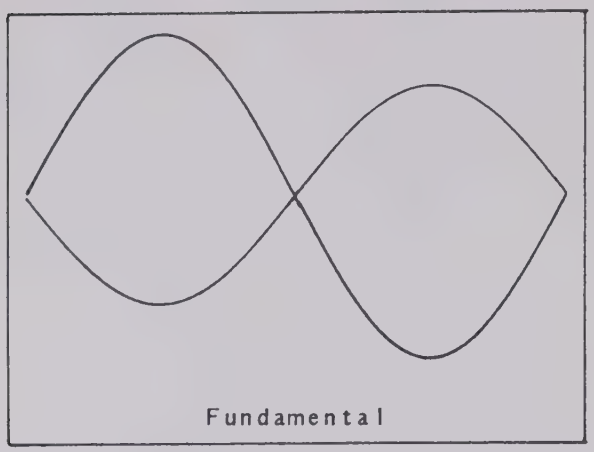
The 3501 analyzer contains a very high "Q" notch filter which rejects the fundamental frequency and leaves all its harmonic contents intact. This notch filter has a steep notch depth of 120dB, typical when properly adjusted. If not, the distortion products viewed on the scope would be at the same frequency as the fundamental.

SECOND HARMONIC DISTORTION -

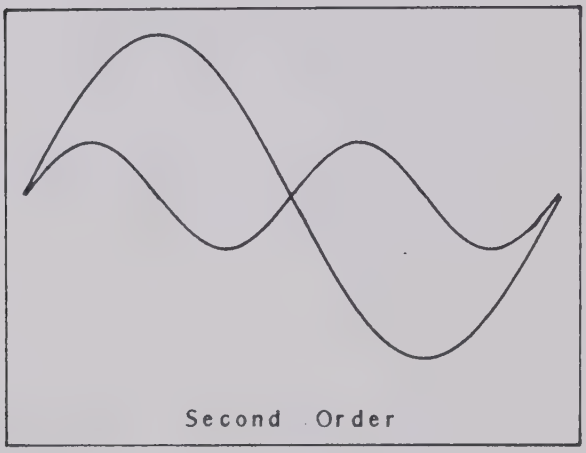
Both oscillator and analyzer in the 3501 contain broad band second harmonic distortion trims. Its presence may be identified by viewing the distortion products on the scope being twice (2x) the frequency of the fundamental.

THIRD HARMONIC DISTORTION -

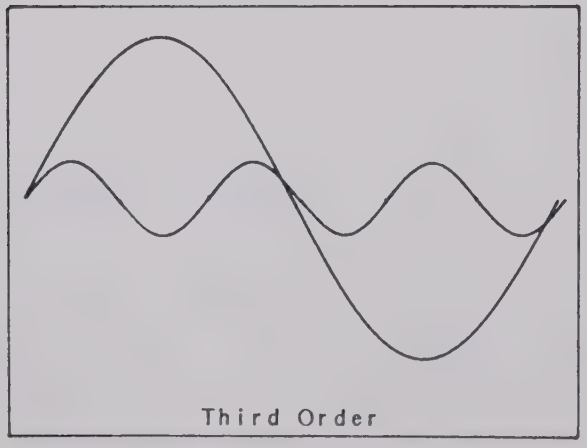
This type of distortion is produced by various device non-linearities and can not be trimmed out in the 3501. However, third order products are typically below the residual 3501 system noise and cannot be visually identified except at the highest frequency range as residual products being three times (3x) the frequency of the fundamental.



Fundamental



Second Order



Third Order

6.3.1 FILTER CIRCUIT CALIBRATION

The five trim adjustments serve the following function and must be calibrated before the oscillator calibration is performed:

V-2001, V-220 – fundamental rejection
V-2003, V-2004 – servo second order trim
V-2005 – filter H.F. "Q" enhancement

These adjustments are critical and will compromise system residual distortion if not correctly set. The proper adjustment requires a very high purity oscillator of known distortion characteristics (1kHz <100dB/0.001% THD). The 3501 oscillator may be used if it is not out of calibration; if it is, see Section 6.3.2.2.

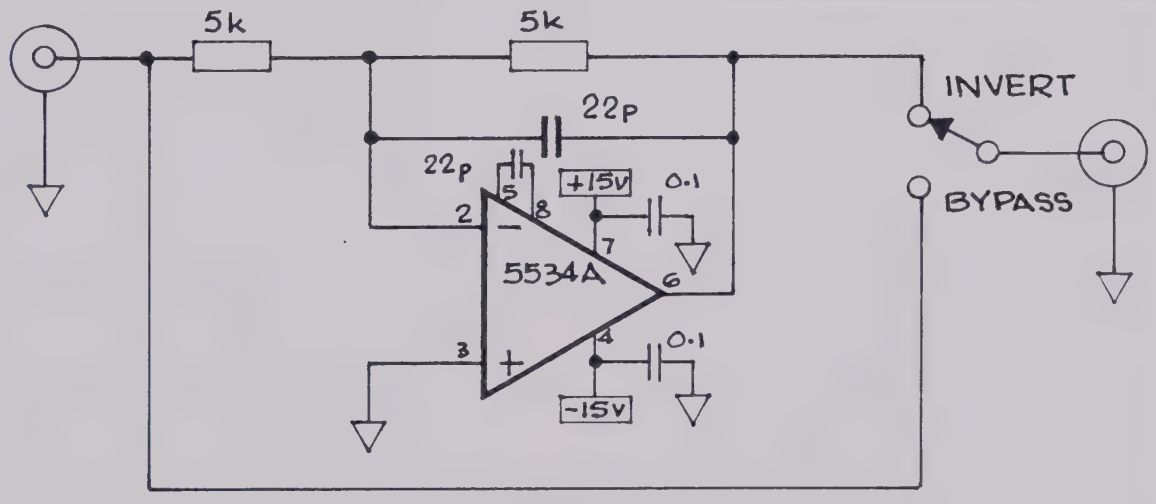
6.3.2.1 FILTER SECOND ORDER TRIM (if 3501 oscillator is properly calibrated)

Set frequency to 1kHz (10 x 100Hz) +10dBV oscillator level and connect to analyzer. Loosen frequency vernier pot shaft coupling between V-2014 and V-2015 with appropriate Allen key driver. This is the drum that couples the front (analyzer) dual pot assembly to the rear (oscillator) dual pot assembly. Loosening the appropriate set screw allows the frequency tracking of the oscillator and analyzer to be modified. This will force the automatic frequency tuning servo

to work harder thus providing greater sensitivity to the adjustments to follow. Set analyzer to measure THD with appropriate front panel setting. Connect monitor outputs to oscilloscope. Turn either V-2014 or V-2015 to obtain 0.0V DC at filter section U-2006, PIN 6. Adjust V-2004 for minimum second harmonic distortion then turn V-2015 until front panel "TUNE HIGH" LED just comes on (the one to the left of the FREQUENCY knob). Adjust V-2003 for minimum second harmonic distortion. The shaft coupling may now be tightened with both V-2014 and V-2015 at their end stops.

6.3.2.2 FILTER SECOND ORDER TRIM (if 3501 oscillator is out of calibration)

The use of an external unity gain inverting amplifier with bypass switch is necessary to overcome the filter/oscillator distortion cancellation/reinforcement. See Section 6.3.0.



NE-5534AN
FIGURE 6.3.2.2 Inverting Stage

The use of this inverting amplifer overcomes the false second harmonic reading which would otherwise be obtained. For example, if the oscillator had second order distortion due to improper adjustment, this distortion could be incorrectly cancelled out using the analyzer adjustments. The instrument would then appear to have no second harmonic distortion but in fact, depending on the nature of the device under test, could exhibit high levels of residual distortion thereby giving erroneous readings. Because second harmonic distortion is asymmetric in nature, the problem can be avoided by adjusting while alternately inverting and not inverting the signal in the measurement path. The conflicting second harmonic null adjustments in both the oscillator and the analyzer are adjusted to give the same residual distortion magnitude in the inverting and non-inverting case. As each of the controls approaches its proper setting, the residual distortion level will gradually be reduced. Iteration between all four controls (2 on the oscillator and 2 on the analyzer) while inverting and not inverting will eventually show complete absence of second order in either mode and result in the instrument achieving its specified performance.

Note that if option 004, Balanced Input, is provided the inversion may be achieved by using the tip or ring input alternately. If option 004 is not included, construct the inverter stage shown in Figure 6.3.2.2. It should be in a shielded box and use good construction practice. Any presence of noise, hum or oscillation will make it useless.

Follow the calibration procedures given in Section 6.3.2.1. The proper adjustments of V-2003 and V-2004 will be such that no change in the residual distortion is detected with the oscillator fed via an inversion or non-inversion. Then trim out oscillator second harmonic distortion with V-2009 and V-2010, if it is out of calibration. Iterate above steps until minimum system residual is achieved. (Typically >-103dBV, 1kHz THD + Noise, band limited at 400Hz H.P. and 30kHz L.P..)

6.3.3 FUNDAMENTAL REJECTION TRIM

With the above setup, adjust V-2201 and V-2202 for minimum fundamental.

6.3.4 FILTER H.F. "Q" ENHANCEMENT TRIM

Connect internal oscillator directly to analyzer. Turn distortion control to 0dB/100%. Set frequency to 100kHz at +10dBV and obtain a reading in the "LEVEL" mode. Switch to band pass mode and adjust V-2005 for the same meter reading as the level mode.

6.3.5 OSCILLATOR CIRCUIT CALIBRATION

The eight trim adjustments serve the following functions:

V-2006 - oscillator level
V-2007 - oscillator HF "Q" enhancement
V-2008 and V-2011 - H.F. second harmonic cancel
V-2009 and V-2010 - Broad band second harmonic cancel
V-2012 - transformer linearization trim
V-2013 - power amplifier bias adjust

Due to the critical nature of the adjustments and oscillator distortion desired (<-104dB/0.006% typical THD + noise at 1kHz), a reference analyzer with low distortion and high notch depth (>115dB) must be used. The 3501 analyzer properly calibrated will serve this function.

Set front panel oscillator level to +10dBV and connect to calibrated 3501 analyzer or external reference analyzer and setup to read THD of the oscillator. Proceed with the following adjustments in the described order.

6.3.6 BROAD BAND SECOND HARMONIC CANCEL

Set oscillator frequency to 1kHz (10 x 100Hz) and adjust V-2009 and V-2010 for minimum second harmonic distortion as viewed on an oscilloscope.

6.3.7 HIGH FREQUENCY SECOND HARMONIC CANCEL

Set oscillator frequency to 70kHz (7 x 10kHz) and adjust V-2008 and V-2011 for minimum second harmonic distortion as viewed on an oscilloscope.

6.3.8 POWER AMPLIFIER BIAS ADJUST

Set oscillator frequency to 70kHz (7 x 10kHz) and adjust V-2013 until the crossover distortion spike just disappears as viewed on an oscilloscope.

6.3.9 OSCILLATOR LEVEL ADJUST

On units with option 005, Balanced Output, set oscillator to MAX position and level pot fully clockwise with FREQUENCY control on front panel at 1kHz. Select balanced output and termination switch pressed in (ON) and adjust V-2006 for maximum output just before clipping occurs. On units without balanced output, adjust V-2006 for +10dBV (3.16V AC) at U-2020, PIN 6.

6.3.10 OSCILLTOR H.F. "Q" ENHANCEMENT ADJUST

Set oscillator to 1kHz (10 x 100Hz) and monitor DC volts at U-2018, PIN 7. Note reading obtained then switch to 100kHz and adjust V-2007 for the same DC volts reading as 1kHz.

The above steps complete the oscillator/filter board calibration. The top cover should be installed.

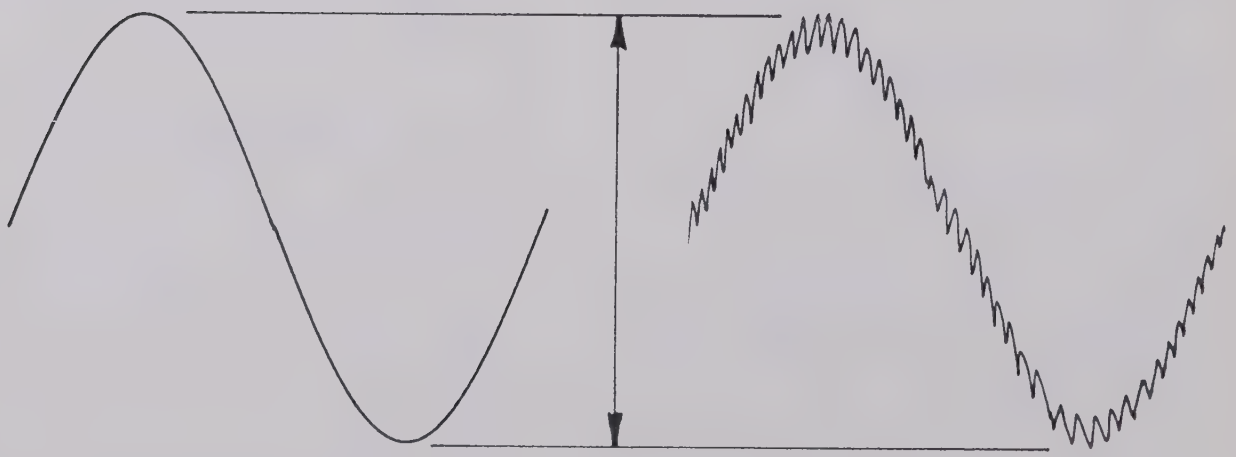
6.3.11 BALANCED OUTPUT DISTORTION NULL

Set the oscillator to 1kHz (10 x 100Hz), balanced output mode, termination on and a level of approximately +18dBm. Connect the OUTPUT to the INPUT by pushing the PUSH FOR OSCILLATOR button and set up the analyzer for a THD reading. Adjust V-2012 for minimum distortion while observing the distortion products on an oscilloscope. This control provides compensation for the non-linearities in the transformer used to achieve the balanced output. With proper adjustment, a reading of -94/0.002% (band limited 400Hz to 30kHz) should be obtained. The adjustment is somewhat temperature dependent and so should be made with the 3501 in a typical ambient temperature environment.

6.4 IMD BOARD (3501-460-02)

This circuit board contains only one trim pot to adjust the low frequency amplitude of the IMD composite source signal. To conform to the SMPTE standard of 4:1 amplitude ratio of the low and high frequency respectively. The calibration procedure is as follows:

Set front panel oscillator controls to +10dBV at 10kHz and connect to analyzer with monitor outputs to an oscilloscope. Note the peak-to-peak sine wave amplitude displaced in the level mode. Switch function to IMD and adjust V-601 for the same peak-to-peak amplitude.



H.F. LEVEL MODE

IMD COMPOSITE

6.5 POWER SUPPLY BOARD (3501-440-02)

This circuit board contains two trim pots and serves the following functions:

V-401 - Battery charge current adjust
V-403 - Output DC rail voltage ±15V and ±22V adjustment

6.5.1 OUTPUT RAIL VOLTAGE ADJUST

Monitor the ±15Volts rail voltage on the left side of the filter/oscillator board (3501-420-02) U-2016, PIN 7 for +15V and PIN 4 for -15V. Adjust V-403 for ±15V DC on this section. The 22 Volt rail is tracking with the 15 Volt rail.

6.5.2 BATTERY CHARGE CURRENT ADJUST

Replace battery with 100 ohm, 5 Watt resistor and adjust V-401 to obtain 14.00 Volts DC across this resistor. This sets the proper charge current for the battery.

6.6 MAINTENANCE SECTION

This section contains information for maintenance and repair of the 3501. The first section is detailed disassembly instructions for each sub-assembly.

6.6.1 3501 DISASSEMBLY INSTRUCTIONS

The disassembly of the 3501 requires only the use of a Phillips screwdriver, except where front panel knobs must be removed, which is descibed below:

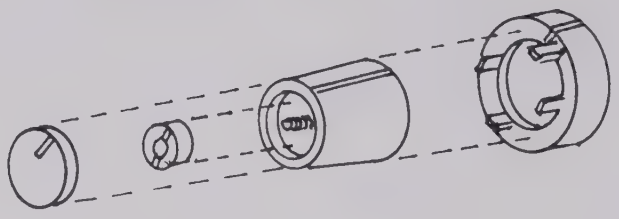


FIGURE 6.6.1 KNOB REMOVAL

Remove front knob cap with a flat blade instrument (XACTO knife) and this will reveal a slotted nut which must be loosened counterclockwise to decouple the knob from its shaft. This could be done by making a slotted screwdriver as shown below.

FIGURE 6.6.2 SPECIAL SCREW DRIVER

CAUTION : Always unplug unit from mains supply when disassembling. Also unplug battery harness on J-404 power supply board where applicable.

6.6.2 ACCESS TO THE FRONT PANEL OUTPUT BOARD (3501-480-02) & IMD BOARD (3501-460-02)

Begin by the removal of the bottom cover which is secured by 4 black Phillips head screws; this will reveal a shield plate that contains the above boards. The right side of the IMD board contains the IMD analyzer and the left side is the low frequency oscillator. A 16 PIN flat cable loops from J-603 to the top layer board (Filter/Oscillator 3501-420-02). The output board (3501-480-02) contains switching for the oscillator output functions as well as the power functions (Power on, Battery charge, Battery test) and the dB relative control.

6.6.3 ACCESS TO THE INPUT METER BOARD (3501-410-02) :

Follow step 1 of above then remove the dB relative knob and 5 side panel screws that secure the shield plate in place. Also remove J-603 flat ribbon cable and J-607, P-801, P-809 Molex harness. By gently lifting rear of shield plate and sliding back the complete assembly it may be swung up, pivoting at the rear of the shield plate. One can then gain access to the Input/Meter board which contains the functions sketched in Figure 6.6.3.

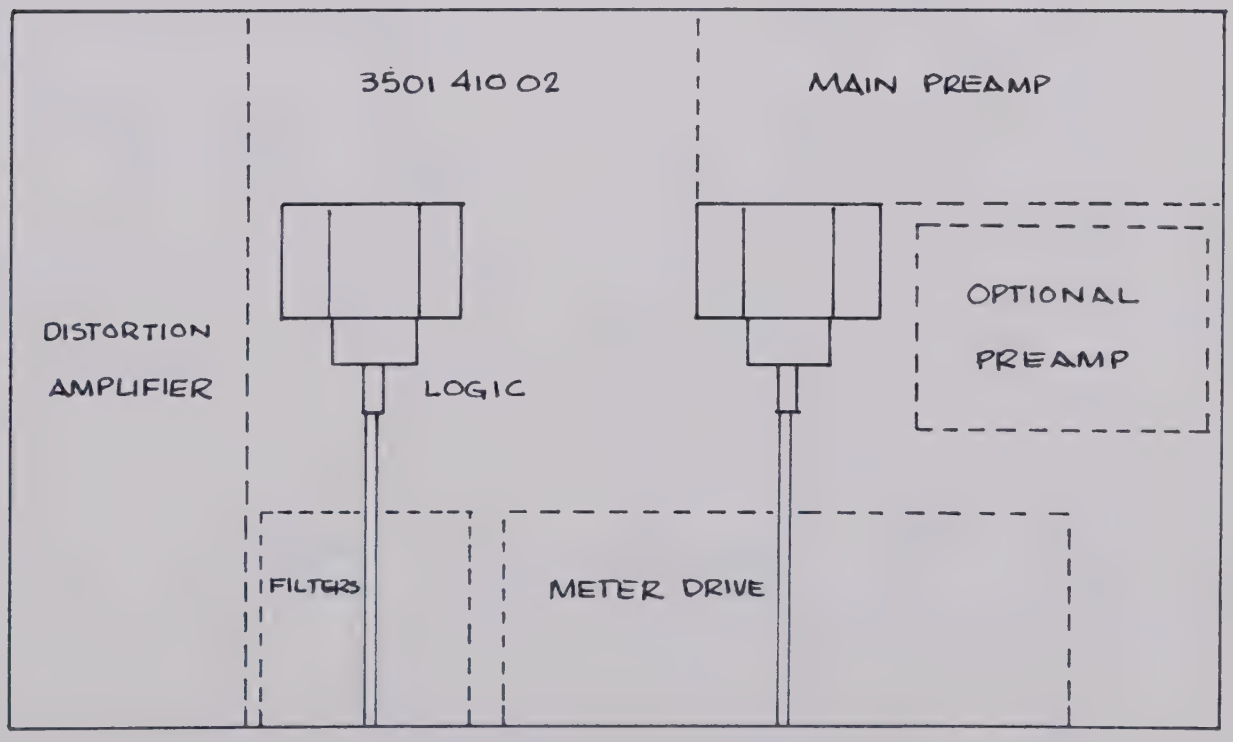


FIGURE 6.6.3 INPUT/METER BOARD FUNCTIONAL LAYOUT

If the removal of this board is required, the front panel is removed to allow the board to slide forward. First remove the front top and bottom dress strips and then the 4 Phillips head screws which secure the front panel to the side panels. Remove all but the frequency select knob which is part of the front panel assembly. Loosening two Allen head screws to the four section frequency pot, V-2014 and V-2015, will enable you to decouple it from its shaft. The front panel may be removed at this point and the Input/Meter board removed by unfastening the 5 screws securing the board to the 3501.

6.6.4 ACCESS TO THE FILTER/OSCILLATOR BOARD (3501-420-02)

Begin by the removal of the top cover which is secured by 4 Phillips head screws. This will reveal the Filter/Oscillator board (3501-420-02) which contains the main oscillator and power amp/attenuator on the right side and the state variable notch filter on the left side. To remove this board, first remove appropriate front panel knobs. The frequency select dial is part of the front panel assembly and may be decoupled from the 4 section frequency pot by loosening 2 Allen head screws. Then remove 5 Phillips screws securing the board and appropriate cables. The board may be slid out from the rear of the front panel.

6.6.5 ACCESS TO THE POWER SUPPLY BOARD (3501-440-02) & SWITCHER ASSEMBLY

The power supply is separated into two parts:

1) Linear section containing AC rectification, regulators and battery charge circuits
2) Switching supply containing the transformer, MOS-FETS and $\pm$22V, $\pm$15V regulated outputs contained in a steel enclosure.

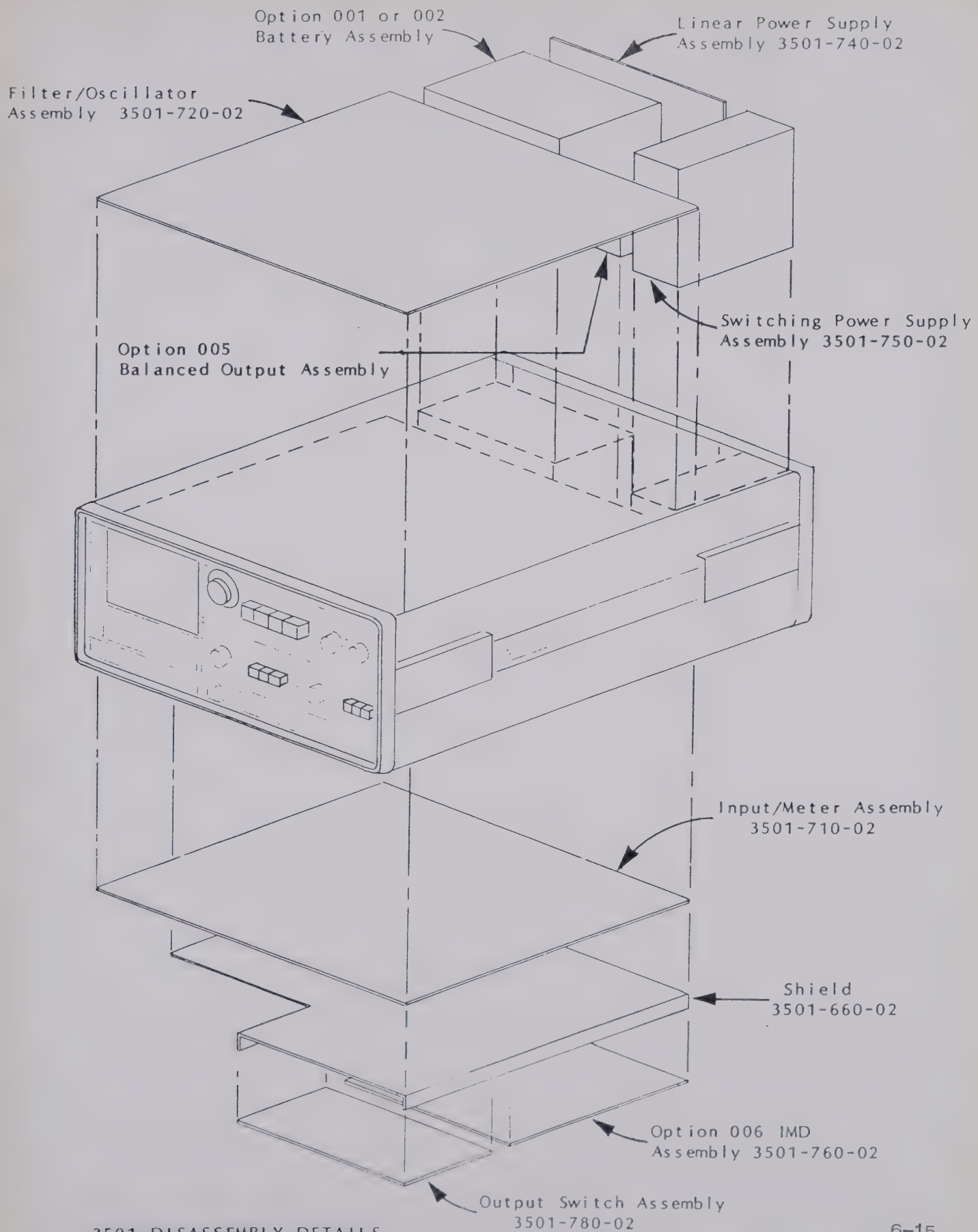
Both of these sections are located on the rear panel and bottom plate of the 3501. The rear panel must be removed so that you can remove either of these assemblies. Proceed with the following steps:

1) Remove both top and bottom covers (8 Phillips screws)
2) Remove rear top and bottom dress strips (6 screws)
3) Remove rear panel assembly, unplug appropriate harnesses (4 screws)

Note the flat cable J-401 orientation

4) Remove switching supply steel enclosure from bottom support plate (2 screws)

Reassemble in reverse order


Option 001 or 002
Battery Assembly
Linear Power Supply
Assembly 3501-740-02
Filter/Oscillator
Assembly 3501-720-02
Switching Power Supply
Assembly 3501-750-02
Option 005
Balanced Output Assembly
Input/Meter Assembly
3501-710-02
Shield
3501-660-02
Option 006 IMD
Assembly 3501-760-02
Output Switch Assembly
3501-780-02

AMBER MODEL 3501

DISTORTION and NOISE

MEASURING SET

Issue 02

August 1982

OWNER'S MANUAL

SECTION 7

PARTS LIST

AMBER ELECTRO DESIGN INC

3501 PARTS LIST — OWNER'S MANUAL

TOTAL ASSEMBLY — ISSUE 06 JANUARY 21, 1983

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	BOTTOM COVER	13501-62102				3501-621-02	1
	KNOB CAP BLACK	63803-11100	11MM		SFM	C111	1
	KNOB CAP BLACK	63803-15100	15MM		SFM	C151	4
	KNOB CAP BLACK	63803-21000	21MM		SFM	C210	1
	CONNECTOR BNC	77001-79131			KING	KC79-131	4
	CONNECTOR 4PIN DIN SOCKET	74004-60400			SWCF	60HA4F	1
	CONNECTOR 4PIN DIN JACK	74004-09400			SWCF	09CL4M	1
	CONNECTOR TRS JACK	76103-11420			SWCF	114B	1
	DRESS NUT					7099	1
	DRESS STRIPS	13501-68003				3501-680-03	4
	FILTER/OSC ASSEMBLY	13501-72002				3501-720-03	1
	FREQUENCY DIAL	35010-61801				3501A61801	1
	FRONT PANEL ASSEMBLY	13501-78002				3501-780-03	1
	FRONT PANEL OVERLAY	13501-61502				3501-615-02	1
	FRONT UNDERLAY PANEL	13501-61002				3501-610-02	1
	CASE HANDLE	65200-78400				7840	2
	HANDLE CLIPS	14500-67501				4500-675-01	4
	HARNESS ASSEMBLY	13501-90501					1
	HEAT SINK	61800-62300				623K	1
	HEAT SINK	61800-44003				3501A648-01 HS	1
	INPUT/METER ASSEMBLY	13501-71002				3501-710-03	1
	KEY CAPS BLACK	63170-39018				80-390108	7
	KEY CAPS DARK GREY	63170-39017				80-390107	7
	KEY CAPS LIGHT GREY	63170-39016				80-390106	2
	KNOB BLACK ROUND	63312-11103	11MM			S111 003	1
	KNOB BLACK WING	63333-15113	15MM			SB151 125	3
	KNOB BLACK ROUND	63313-15112	15MM			S151-125	1
	KNOB	63313-21000	21MM			S210 250	1
	LINEAR POWER SUPPLY ASSEMBLY	13501-74002				3501-740-03	1
	MAIN CHASSIS	13501-63002				3501-630-02	1
	TRANSFORMER 40 VA	53504-31610	40VA			316-1040	1
	METER 3.5 INCHES	55381-00192	1MA			T3LC-DMA-001-G1	1
	NUT COVER BLACK	63803-11101	11MM			N111	1
	NUT COVER BLACK	63803-15101	15MM			N151	4
	OPTION CHASSIS	13501-66002				3501-660-02	1
	PLUG BUTTON METAL					B-1840N	2
	CONNECTOR PANEL POST BLACK	74001-15170				1517	1
	POWER SUPPLY BOX	13501-64501				3501-645-01	1
	POWER SUPPLY CHASSIS	13501-64002				3501-640-02	1
	POWER SUPPLY COVER	13501-64601				3501-646-01	1
	RATIO DRIVE	62000-06100				RDL-61	1

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	REAR PANEL (SCREENED)	13501-67002				3501-670-02	1
	SCREW 10-32 FLAT BLACK					0.5 INCH	4
	SCREW 6-32 FLAT BLACK	61113-16025	FH			AN 507-632R4	16
	SCREW 6-32 FLAT YELLOW					0.25 INCH	27
	SIDE BRACKET	13501-65002				3501-650-02	2
	MACHINE SPRING NUTS 6-32	61240-54000				TN-226	20
	SWITCH TOGGLE SPDT	87232-71010				7101SYZG	1
	SWITCHING SUPPLY ASSEMBLY	13501-75002				3501-750-03	1
	CASE TILT BAIL 9.6	65300-40809			BCYE	MP 40008 9.6	1
	TOP COVER	13501-62002				3501-620-02	1

INPUT METER

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	HEADERS 4 PIN				MOLX	22-10-2041	4
	CONNECTOR SOCKET PCB DIL 14PIN	71014-21439			AUGT	214-AG39D	9
	CONNECTOR SOCKER PCB DIL 16PIN	71016-21639			AUGT	216-AG39D	6
	CONNECTOR SOCKET PCB DIL 8PIN	71008-20839			AUGT	208-AG39D	12
	CONNECTOR HEADER LATCH 4PIN	78003-20410			MOLX	22-29-2041	10
	CONNECTOR SOCKET PCB DIL 16PIN	71516-51600	MACH			516-AG11D	5
	PRINTED CIRCUIT BOARD	13501-41003			AMBR	3501-410-03	1
	SHAFT EXTENSIONS				AMBR		2
	FUSE CLIPS				LTLF	102068	2
	SHAFTING COUPLERS	61729-15150			JAN	AP15150 - 1/8	2
C1001	CAPACITOR CERAMIC DISC	41033-04700	47P	20%		GH470K	4
C1002	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	10
C1003	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C1004	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		12
C1005	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C1006	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C1007	CAPACITOR FILM	45042-47030	0.47	20%		MKS3 0.47/63/20W	1
C1008	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C1009	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C1010	CAPACITOR CERAMIC DISC	41033-03000	30P	20%		DD300	4
C1011	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C1011	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C1012	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C1013	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C1014	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C1015	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C1016	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C1017	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C1018	CAPACITOR/NOT USED						
C1019	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C1020	CAPACITOR CERAMIC DISC	41033-15000	150P	20%		DB201-25P-151	3
C1021	CAPACITOR CERAMIC DISC	41033-02200	22P	20%			2
C1022	CAPACITOR FILM	45042-10030	0.1	20%		MKS3 0.1/100/20W	2
C1023	CAPACITOR/NOT USED						
C1024	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C1025	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C1026	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C1027	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C1028	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C1029	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C1030	CAPACITOR ALUM ELE AXIL 22/25	48030-02200	22	20%	SIEM		2
C1031	CAPACITOR ALUM ELE AXIL 22/25	48030-02200	22	20%	SIEM		
C1032	CAPACITOR FILM	45042-10030	0.1	20%		MKS3 0.1/100/20W	
C1033	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			2
C1034	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
C 035	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			
C 036	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			16
C 037	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 038	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 039	CAPACITOR CERAMIC DISC	41033-15000	150P	20%		DB201-25P-151	
C 040	CAPACITOR CERAMIC DISC	41033-10000	100P	20%			4
C 041	CAPACITOR CERAMIC DISC	41033-03000	30P	20%		DD300	
C 042	CAPACITOR/NOT USED						
C 043	CAPACITOR/NOT USED						
C 044	CAPACITOR CERAMIC DISC	41033-04700	47P	20%		GH470K	
C 045	CAPACITOR CERAMIC DISC	41033-10000	100P	20%			
C 046	CAPACITOR CERAMIC DISC	41033-15000	150P	20%		DB201-25P-151	
C 047	CAPACITOR CERAMIC DISC	41033-33000	330P	20%			1
C 048	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C 049	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 050	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 051	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	9
C 052	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C 053	CAPACITOR ALUM ELE AXIL 220/40	48050-22000	220	20%	SIEM		
C 054	CAPACITOR ALUM ELE AXIL 220/40	48050-22000	220	20%	SIEM		2
C 055	CAPACITOR CERAMIC DISC	41033-04700	47P	20%		GH470K	
C 056	CAPACITOR CERAMIC DISC	41033-03000	30P	20%		DD300	
C 057	CAPACITOR CERAMIC DISC	41033-02200	22P	20%			
C 058	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 059	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 060	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 061	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 062	CAPACITOR FILM	45042-10030	0.01	20%			2
C 063	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 064	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 065	CAPACITOR FILM	45042-10030	0.01	20%			
C 066	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 067	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 068	CAPACITOR FILM	45042-10040	1.0	20%		MKS3 1.0/63/20W	2
C 069	CAPACITOR FILM	45042-10040	1.0	20%		MKS3 1.0/63/20W	
C 070	CAPACITOR FILM	45042-10010	1000P	20%		FKC3 1000/160/20W	1
C 071	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C 072	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%	ITT		
C 073	CAPACITOR CERAMIC DISC	41033-04700	47P	20%		GH470K	
C 074	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C 075	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C 076	CAPACITOR ALUM ELE AXIL 4.7/40	48050-04790	4.7	20%		85200/4.7/40V	1
C 077	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 078	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 079	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C 080	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%			
C 081	CAPACITOR CERAMIC DISC	41033-03000	30P	20%		DD300	
C 082	CAPACITOR CERAMIC DISC	41033-10000	100P	20%			

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
C1083	CAPACITOR CERAMIC DISC	41033-10000	100P	20%			
D1001	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	13
D1002	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1003	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1004	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1005	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1006	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1007	SEMICON DIODE ZENER 1W	21135-47480	22V			1N4748	2
D1008	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1009	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1010	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1011	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	2
D1012	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
D1013	SEMICON DIODE ZENER 1W	21135-47480	22V			1N4748	
D1014	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1015	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1016	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1017	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D1018	SEMICON LED RECT RED	21525-57124			GI	MV57124	2
D1019	SEMICON LED RECT RED	21525-57124			GI	MV57124	
F1101	FUSE 3AG FAST	85312-06210	63MA		LTLF	312062	1
J1001	CONNECTOR FLAT CABLE 16PIN PC	72016-16780				609-1678	2
J1002	CONNECTOR FLAT CABLE 16PIN PC	72016-16780				609-1678	
N1001	RESISTOR NET 16PIN 15 RES DIL	38235-10030	100K			1615-104G	1
N1002	RESISTOR NET 16PIN 8 RES DIL	38435-22020	22K			1608-223G	1
Q1001	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	5
Q1002	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q1003	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	4
Q1004	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q1005	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q1006	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q1007	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q1008	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q1009	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q1010	SEMICON FET N CHANNEL	22392-07300				J-111	2
Q1011	SEMICON FET N CHANNEL	22392-07300				J-111	
R1001	RESISTOR CF 1/4W	32033-10000	100	5%			
R1002	RESISTOR CF 1/4W	32022-10030	100K	5%			
R1003	RESISTOR CF 1/4W	32033-10000	100	5%			13
R1004	RESISTOR CF 1/4W	32033-10000	100	5%			
R1005	RESISTOR MF 1/4W	32035-22100	221	1%		2210F	2
R1006	RESISTOR CF 1/4W	32033-33000	330	5%			
R1007	RESISTOR MF 1/4W	32035-10010	1K00	1%		1001F	3
R1008	RESISTOR MF 1/4W		3K16	0.1%			3
R1009	RESISTOR MF 1/4W		1K00	0.1%			4
R1010	RESISTOR MF 1/4W		464	0.1%			1
R1011	RESISTOR CF 1/4W	32033-10000	100	5%			
R1012	RESISTOR CF 1/4W	32033-10000	100	5%			

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R1013	RESISTOR MF 1/4W		2K00	0.1%			1
R1014	RESISTOR MF 1/4W		432	0.1%			1
R1015	RESISTOR CF 1/4W	32033-10020	10K	5%			15
R1016	RESISTOR MF 1/4W		562	0.1%			2
R1017	RESISTOR CF 1/4W	32033-10050	10M	5%			1
R1018	RESISTOR CF 1/4W	32033-10010	1K0	5%			3
R1019	RESISTOR CF 1/4W	32033-10000	100	5%			
R1020	RESISTOR CF 1/4W	32033-10000	100	5%			
R1021	RESISTOR CF 1/4W	32033-47000	470	5%			
R1022	RESISTOR CF 1/4W	32033-10000	100	5%			
R1023	RESISTOR CF 1/4W	32033-10000	100	5%			
R1024	RESISTOR MF 1/4W	32035-22100	221	1%		2210F	
R1025	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1026	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1027	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1028	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1029	RESISTOR MF 1/4W		1K00	0.1%			
R1030	RESISTOR MF 1/4W		9K09	0.1%			1
R1031	RESISTOR MF 1/4W	32035-10010	1K00	1%		1001F	
R1032	RESISTOR MF 1/4W	32035-20010	2K00	1%		2001F	1
R1033	RESISTOR MF 1/4W		9K76	0.1%			1
R1034	RESISTOR MF 1/4W	32035-10000	100	0.1%			1
R1035	RESISTOR CF 1/4W	32033-22020	22K	5%			3
R1036	RESISTOR MF 1/4W		10K0	0.1%			1
R1037	RESISTOR CF 1/4W	32033-30010	3K0	5%			1
R1038	RESISTOR MF 1/4W	32035-20020	20K	1%		2002F	2
R1039	RESISTOR MF 1/4W	32035-12120	12K1	1%		1212F	2
R1040	RESISTOR CF 1/4W	32033-68000	680	5%			
R1041	RESISTOR MF 1/4W	32035-12120	12K1	1%		1212F	
R1042	RESISTOR MF 1/4W	32035-20020	20K	1%		2002F	
R1043	RESISTOR CF 1/4W	32033-68000	680	5%			2
R1044	RESISTOR MF 1/4W	32035-60410	6K04	1%			2
R1045	RESISTOR MF 1/4W	32035-66500	665	1%			2
R1046	RESISTOR MF 1/4W	32035-66500	665	1%			
R1047	RESISTOR MF 1/4W	32035-60410	6K04	1%			
R1048	RESISTOR CF 1/4W	32033-20010	2K0	5%			3
R1049	RESISTOR CF 1/4W	32033-20010	2K0	5%			
R1050	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1051	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1052	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1053	RESISTOR CF 1/4W	32033-10040	1M0	5%			1
R1054	RESISTOR CF 1/4W	32033-22020	22K	5%			
R1055	RESISTOR MF 1/4W	32035-10010	1K00	1%		1001F	
R1056	RESISTOR MF 1/4W	32035-24920	24K9	1%		2492F	1
R1057	RESISTOR NOT USED						
R1058	RESISTOR MF 1/4W		1K00	0.1%			
R1059	RESISTOR MF 1/4W		3K16	0.1%			
R1060	RESISTOR CF 1/4W	32033-12020	12K	5%			2

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R1061	RESISTOR MF 1/4W		6K81	0.1%			2
R1062	RESISTOR MF 1/4W		21K5	0.1%			2
R1063	RESISTOR CF 1/4W	32033-18020	18K	5%			2
R1064	RESISTOR CF 1/4W	32033-30020	30K	5%			1
R1065	RESISTOR MF 1/4W		68K1	0.1%			2
R1066	RESISTOR NOT USED						
R1067	RESISTOR CF 1/4W	32033-47000	470	5%			3
R1068	RESISTOR NOT USED						
R1069	RESISTOR MF 1/4W		68K1	0.1%			
R1070	RESISTOR CF 1/4W	32033-12020	12K	5%			
R1071	RESISTOR CF 1/4W	32033-18020	18K	5%			
R1072	RESISTOR MF 1/4W		21K5	0.1%			
R1073	RESISTOR MF 1/4W		6K81	0.1%			
R1074	RESISTOR CF 1/4W	32033-22020	22K	5%			
R1075	RESISTOR MF 1/4W		3K16	0.1%			
R1076	RESISTOR NOT USED						
R1077	RESISTOR MF 1/4W		1K00	0.1%			
R1078	RESISTOR MF 1/4W		2K32	0.1%			1
R1079	RESISTOR MF 1/4W		549	0.1%			1
R1080	RESISTOR MF 1/4W		162	0.1%			1
R1081	RESISTOR CF 1/4W	32033-36000	360	5%			1
R1082	RESISTOR CF 1/4W	32033-33000	330	5%			3
R1083	RESISTOR CF 1/4W	32033-06200	62	5%			2
R1084	RESISTOR CF 1/4W	32033-06200	62	5%			
R1085	RESISTOR CF 1/4W	32033-33000	330	5%			
R1086	RESISTOR CF 1/4W	32033-47010	4K7	5%			3
R1087	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R1088	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R1089	RESISTOR CF 1/4W	32033-47090	47	5%			1
R1090	RESISTOR MF 1/4W		4K99	0.1%			2
R1091	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1092	RESISTOR CF 1/4W	32033-13000	130	5%			1
R1093	RESISTOR MF 1/4W		2K49	0.1%			2
R1094	RESISTOR MF 1/4W		562	0.1%			
R1095	RESISTOR MF 1/4W		2K49	0.1%			
R1096	RESISTOR MF 1/4W		4K99	0.1%			
R1097	RESISTOR MF 1/4W	32035-11010	1K10	1%			1
R1098	RESISTOR CF 1/4W	32033-20020	20K	5%			1
R1099	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	4
R1100	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1101	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1102	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1103	RESISTOR MF 1/4W	32035-12130	121K	1%			2
R1104	RESISTOR MF 1/4W	32035-10020	10K0	1%			
R1105	RESISTOR MF 1/4W	32035-12130	121K	1%			
R1106	RESISTOR MF 1/4W	32035-24910	2K49	1%		2491F	1
R1107	RESISTOR MF 1/4W	32035-88710	8K87	1%		8871F	1
R1108	RESISTOR MF 1/4W	32035-49900	499	1%		4990F	1

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R1109	RESISTOR MF 1/4W	32035-10030	100K	1%		1003F	1
R1110	RESISTOR MF 1/4W	32035-44220	44K2	1%		4422F	1
R1111	RESISTOR MF 1/4W	32035-33200	332	1%		3320F	1
R1112	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R1113	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1114	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R1115	RESISTOR CF 1/4W	32033-10020	10K	5%			
R1116	RESISTOR MF 1/4W	32035-06650	66R5	1%			1
R1117	RESISTOR CF 1/4W	32033-47000	470	5%	BRNS		
R1118	RESISTOR MF 1/4W	32035-47500	475	1%		4750F	1
R1119	RESISTOR CF 1/4W	32033-02200	22	5%			1
R1120	RESISTOR MF 1/4W	32035-49930	499K	1%		4993F	1
R1121	RESISTOR MF 1/4W	32035-49920	49K9	1%		4992F	1
R1123	RESISTOR MF 1/4W	32035-49920	4K12	1%		4121F	1
R1124	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R1125	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R1126	RESISTOR CF 1/4W	32033-10000	100	5%			
R1127	RESISTOR CF 1/4W	32033-10000	100	5%			
R1128	RESISTOR CF 1/4W	32033-10030	100K	5%			2
R1130	RESISTOR CF 1/4W	32033-10000	100	5%			
R1131	RESISTOR CF 1/4W	32033-10000	100	5%			
R1132	RESISTOR CF 1/4W	32033-20010	2K0	5%			
R1133	RESISTOR CF 1/4W	32033-10020	10K	5%			
S1001	SWITCH ROTARY 3 POLE 11 POS	81311-31311				31-X30-M-11	2
S1002	SWITCH ROTARY 3 POLE 11 POS	81311-31311				31-X30-M-11	
S1003	SWITCH PUSHBUTTON 2U	84211-01001			SCHW	F2UEE	3
S1004	SWITCH PUSHBUTTON 2U	84211-01001			SCHW	F2UEE	
S1005	SWITCH PUSHBUTTON 2U	84211-01001			SCHW	F2UEE	
S1006	SWITCH PUSHBUTTON	82291-10000			SCHW	F10GR2U	3
S1007	SWITCH PUSHBUTTON	82291-10000			SCHW	F10GR2U	
S1008	SWITCH PUSHBUTTON	82291-10000			SCHW	F10GR2U	
S1009	SWITCH PUSHBUTTON	82620-06000			SCHW	F6UEE	1
U1001	SEMICON OP AMP LO NOISE LIN	25511-55340			SIG	NE5534AN	3
U1002	SEMICON CMOS SWITCH	24021-40530				CD4053B	5
U1003	SEMICON OP AMP J FET	25311-35700				LF357N	1
U1005	SEMICON OP AMP PRECISION	25311-31800			NSC	LM318N	2
U1006	SEMICON CMOS SWITCH	24021-40530				CD4053B	
U1007	SEMICON OP AMP PRECISION	25311-31800			NSC	LM318N	
U1008	SOCKET						1
U1009	SEMICON OP AMP BI-FET DUAL	25211-07200			TI	TL072CP	
U1010	FILTER NETWORK LP		80K				1
U1011	FILTER NETWORK LP		30K				1
U1012	SEMICON OP AMP BI-FET DUAL	25211-07200				TL072CP	2
U1013	FILTER NETWORK HP		400HZ				1
U1014	SEMICON SHUNT REGULATOR	25992-43100				TL431CLP	2
U1015	SEMICON SHUNT REGULATOR	25992-43100				TL431CLP	
U1016	SEMICON CMOS SWITCH	24021-40530				CD4053B	
U1017	SEMICON CMOS SWITCH	24021-40530				CD4053B	

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
U1018	SEMICON CMOS OR GATE	24021-40720				CD4072B	
U1019	SEMICON CMOS OR GATE	24021-40720				CD4072B	
U1020	SEMICON CMOS QUAD IN OR GATE	24021-40710				CD4071B	1
U1021	SEMICON CMOS OR GATE	24021-40750				CD4075B	1
U1022	SEMICON CMOS OR GATE	24021-40720				CD4072B	5
U1023	SEMICON CMOS OR GATE	24021-40720				CD4072B	
U1024	SEMICON CMOS DECODER 1 TO 10	24021-40280				CD4028B	1
U1025	SEMICON CMOS OR GATE	24021-40720				CD4072B	
U1026	SEMICON RMS TO DC CONVERTER	25000-53600			ANLG	AD536AJD	2
U1027	SEMICON RMS TO DC CONVERTER	25000-53600			ANLG	AD536AJD	
U1028	SEMICON OP AMP LO NOISE LIN	25511-55340			SIG	NE5534AN	
U1029	SEMICON DUAL N CH FET	22318-25146			TOS	2SK146GR	1
U1030	SEMICON OP AMP LO NOISE LIN	25511-55340			SIG	NE5534AN	
U1031	NOT USED						
U1032	SEMICON OP AMP LO-OFFSET FET	25411-41200				LF412N	1
U1033	DUAL TRANSISTOR NPN				NSC	LM394	1
U1034	SEMICON CMOS SWITCH	24021-40530				CD4053B	
U1035	SEMICON OP AMP BI-FET DUAL	25211-06200			TI	TL062CP	2
U1036	SEMICON OP AMP BI-FET DUAL	25211-06200			TI	TL062CP	
V1117	RESISTOR TRIM CONTROL MT	51515-50020	50K		BRNS	3299W-1-503	
V1122	RESISTOR TRIM CONTROL MT	51515-05000	50		BRNS	3299W-1-500	1
V1126	RESISTOR TRIM CONTROL MT	51515-50020	50K		BRNS	3299W-1-503	5
V1127	RESISTOR TRIM CONTROL MT	51515-50020	50K		BRNS	3299W-1-503	
V1128	RESISTOR TRIM CONTROL MT	51515-50020	50K		BRNS	3299W-1-503	
V1129	RESISTOR TRIM CONTROL MT	51515-50000	500		BRNS	3299W-1-501	1
V1130	RESISTOR TRIM CONTROL MT	51515-50020	50K		BRNS	3299W-1-503	

FILTER/OSCILLATOR

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	ROTARY SWITCH 3 POL 11 POS	81311-31311			RCL	31X30M-11	1
	SHAFTING COUPLERS	61729-15150			JAN	AP15150-1/8	2
	SW SHAFT EXTENSION				AMBR		1
	CONNECTOR SOCKET PCB DIL 14PIN	71014-21439			AUGT	214-AG39D	2
	CONNECTOR SOCKET PCB DIL 16PIN	71016-21639			AUGT	216-AG39D	4
	CONNECTOR SOCKET PCB DIL 8PIN	71008-20839			AUGT	208-AG39D	22
	CONNECTOR HEADER LATCH 4PIN	78003-20410			MOLX	22-29-2041	10
	PRINTED CIRCUIT BOARD	13501-42003			AMBR	3501-420-03	1
	FREQUENCY POT SHIELD				AMB		
	TEST POINT PINS				AMB		
	RCL SWITCH SECTION SHIELD				AMB		
C2001	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			35
C2002	CAPACITOR PLASTIC FILM		0.01	20%			1
C2003	CAPACITOR FILM	45042-10030	0.1	20%		MKS3 0.1/100/20W	2
C2004	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2005	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2006	CAPACITOR FILM		0.22	20%			4
C2007	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2008	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2009	CAPACITOR CERAMIC DISC	41033-03390	3P3	20%		DD3RC	4
C2010	CAPACITOR CERAMIC DISC	41033-03390	3P3	20%		DD3RC	
C2011	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2012	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2013	NOT USED						
C2014	NOT USED						
C2015	NOT USED						
C2016	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2017	CAPACITOR FILM		0.22	20%			
C2018	CAPACITOR FILM		0.22	20%			
C2019	CAPACITOR FILM	45042-10040	1.0	20%		MKS3 1.0/63/20W	2
C2020	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			8
C2021	CAPACITOR TANTALUM 1.5/225V	47031-01590	1.5	20%			
C2022	CAPACITOR FILM	45042-10040	1.0	20%		MKS3 1.0/63/20W	
C2023	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			
C2024	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			
C2025	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2026	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%			
C2027	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	8
C2028	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%			
C2029	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2030	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C2031	CAPACITOR CERAMIC DISC	41033-33000	330P	20%			3
C2032	CAPACITOR CERAMIC DISC	41033-02200	22P	20%			5
C2033	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2034	CAPACITOR CERAMIC DISC	41033-10000	100P	20%		ARCO	4

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
C2035	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2036	CAPACITOR CERAMIC NPO		220P	1%	VIT	VP12BA221F	4
C2037	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C2038	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2039	CAPACITOR CERAMIC DISC	40133-10030	0.01	20%			
C2040	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C2041	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2042	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2043	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2044	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2045	CAPACITOR CERAMIC NPO		220P	1%	VIT	VP12BA221F	
C2046	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2047	CAPACITOR CERAMIC DISC	41033-10000	100P	20%		ARCO	
C2048	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2049	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2050	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2051	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C2052	CAPACITOR CERAMIC DISC	41033-02200	22P	20%			
C2053	CAPACITOR CERAMIC NPO		2000P	1%	VIT	VP12BA202F	4
C2054	CAPACITOR FILM SELECTED	45044-22021	0.022	SEL	WIMA	MKS2 0.022/63/5W	4
C2055	CAPACITOR FILM SELECTED	45044-22031	0.22	SEL	WIMA	MKS2 0.22/63/5W	4
C2056	CAPACITOR FILM SELECTED	45044-22031	0.22	SEL	WIMA	MKS2 0.22/63/5W	
C2057	CAPACITOR FILM SELECTED	45044-22021	0.022	SEL	WIMA	MKS2 0.022/63/5W	
C2058	CAPACITOR CERAMIC NPO		2000P	1%	VIT	VP12BA202F	
C2059	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			
C2060	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2064	CAPACITOR FILM	45042-47010	4700P	5%		FKC3 4700/160/5W	1
C2065	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2066	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2067	CAPACITOR FILM	45042-47030	0.47	20%		MKS3 0.47/63/20W	1
C2068	CAPACITOR CERAMIC NPO		220P	1%	VIT	VP12BA221F	
C2069	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2070	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2071	CAPACITOR CERAMIC DISC	41033-10000	100P	20%			
C2072	CAPACITOR CERAMIC NPO		220P	1%	VIT	VP12BA221F	
C2073	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2074	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2075	CAPACITOR ALUM ELE AXIAL 10/40	48050-01000	10	20%		85200/10/40V	1
C2076	CAPACITOR CERAMIC DISC	41033-03000	30P	5%		DD300	1
C2077	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			
C2078	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2079	CAPACITOR CERAMIC DISC	41033-02200	22P	20%			
C2080	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C2081	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%			
C2082	CAPACITOR CERAMIC DISC	41033-10000	100P	20%			

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
C2083	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%			
C2084	CAPACITOR FILM SELECTED	45044-22031	0.22	SEL	WIMA	MKS2 0.22/63/5W	
C2085	CAPACITOR FILM SELECTED	45044-22021	0.022	SEL	WIMA	MKS2 0.022/63/5W	
C2086	CAPACITOR CERAMIC NPO		2000P	1%	VIT	VP12BA202F	
C2087	CAPACITOR FILM SELECTED	45044-22031	0.22	SEL	WIMA	MKS2 0.22/63/5W	
C2088	CAPACITOR FILM SELECTED	45044-22021	0.022	SEL	WIMA	MKS2 0.022/63/5W	
C2089	CAPACITOR CERAMIC NPO		2000P	1%	VIT	VP12BA202F	
C2090	CAPACITOR CERAMIC DISC	41033-03390	3P3	20%		DD3RC	
C2091	CAPACITOR CERAMIC DISC	41033-03390	3P3	20%		DD3RC	
C2092	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2093	CAPACITOR ALUM ELE RAD 10/40	48050/01000	10	20%		85200/10/40V	
C2094	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2095	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C2096	CAPACITOR CERAMIC DISC	41033-33000	330P	20%			
C2097	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C2098	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C2099	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C2100	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C2101	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C2102	CAPACITOR FILM	45042-33000	330P	20%		FKC3 330/160/20W	1
C2103	CAPACITOR FILM	45042-22030	0.22	5%		MKS2 0.22/63/5W	
C2104	CAPACITOR CERAMIC DISC	41033-02200	22P	20%			
C2105	CAPACITOR MONO CERAMIC	42031-10030	0.1	20%		B37988J5104M	3
C2106	CAPACITOR MONO CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C2107	CAPACITOR CERAMIC DISC	41033-02200	22P	20%			
C2108	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C2109	CAPACITOR MONO CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C2110	CAPACITOR CERAMIC DISC	41033-15000	150P	20%		DB 210-25P-151	1
C2111	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	8
C2112	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2113	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C2114	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C2115	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			
C2116	CAPACITOR CERAMIC DISC		220P	20%			1
C2117	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			
C2118	CAPACITOR ALUM ELE AXIAL 22/25	48030-02200	22	20%			1
D2001	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	38
D2002	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2003	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2004	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2005	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2006	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2007	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2008	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2009	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2010	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2011	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2012	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
D2013	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2014	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2016	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2017	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2018	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2019	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2020	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2021	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2022	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2023	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2024	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2025	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2026	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2027	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2028	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2029	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2030	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2031	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2032	SEMICON DIODE ZENER	21207-07531	6.2V			1N753A	2
D2033	SEMICON DIODE ZENER	21207-07531	6.2V			1N753A	
D2034	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2035	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2036	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2038	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2039	SEMICON DIODE SHOTTKY	21107-62630				1N6263	1
D2040	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2041	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D2042	SEMICON RECTIFIER	21135-40040	200V			1N4004	4
D2043	SEMICON RECTIFIER	21135-40040	200V			1N4004	
D2044	SEMICON DIODE ZENER	21207-07511	5.1V			1N751A	2
D2045	SEMICON DIODE ZENER	21207-07511	5.1V			1N751A	
D2046	SEMICON RECTIFIER	21135-40040	200V			1N4004	
D2047	SEMICON RECTIFIER	21135-40040	200V			1N4004	
F2015	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
F2037	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
J2001	CONNECTOR FLAT CABLE 16PIN	72016-16780			ANSL	609-1678	2
J2001	CONNECTOR FLAT CABLE 16PIN	72016-16780			ANSL	609-1678	
L2001	SEMICON LED RECT RED	21525-57124			GI	MV57124	2
L2002	SEMICON LED RECT RED	21525-57124			GI	MV57124	
Q2001	SEMICON FET N CHANNEL	22392-07300				J-111	4
Q2002	SEMICON FET P CHANNEL	22492-38200				2N3820	3
Q2003	SEMICON FET N CHANNEL	22392-07300				J-111	
Q2004	SEMICON FET P CHANNEL	22492-38200				2N3820	
Q2005	SEMICON FET N CHANNEL	22392-07300				J-111	
Q2006	SEMICON FET P CHANNEL	22492-38200				2N3820	
Q2007	SEMICON FET N CHANNEL	22392-07300				J-111	
Q2008	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	3
Q2009	SEMICON SHUNT REGULATOR	25992-43100				TL431CLP	1

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
Q2010	SEMICON FET N CHANNEL	22318-48610				2N4861	1
Q2011	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	6
Q2012	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q2013	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q2014	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q2015	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q2016	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q2017	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q2018	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q2019	SEMICON TRANSISTOR NPN POWER	22522-00700				MPSU07	1
Q2020	SEMICON TRANSISTOR PNP POWER	22622-05000			MOT	MPSU57	1
Q2021	SEMICON LED/LDR	20005-85000			CLRX	CLM8500	1
R2001	RESISTOR CF 1/4W	32025-20030	200K	5%		2003F	1
R2002	RESISTOR CF 1/4W	32033-12040	1M2	5%			1
R2003	RESISTOR CF 1/4W	32033-10050	10M	5%			4
R2004	RESISTOR CF 1/4W	32033-22020	22K	5%			
R2005	RESISTOR CF 1/4W	32033-33020	33K	5%			1
R2006	RESISTOR CF 1/4W	32033-10040	1M0	5%			2
R2007	RESISTOR CF 1/4W	32033-10030	100K	5%			10
R2008	RESISTOR CF 1/4W	32033-47030	470K	5%			1
R2009	RESISTOR CF 1/4W	32033-10010	1K0	5%			6
R2010	RESISTOR CF 1/4W	32033-20020	20K	5%			1
R2011	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R2012	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R2013	RESISTOR CF 1/4W	32033-10030	100K	5%			
R2014	RESISTOR CF 1/4W	32033-10030	100K	5%			
R2015	RESISTOR CF 1/4W	32033-10050	10M	5%			
R2016	RESISTOR CF 1/4W	32033-39010	3K9	5%			2
R2017	RESISTOR CF 1/4W	32033-22040	2M2	5%			2
R2018	RESISTOR CF 1/4W	32033-10050	10M	5%			
R2019	RESISTOR CF 1/4W	32033-10040	1M0	5%			
R2020	RESISTOR CF 1/4W	32033-39010	3K9	5%			
R2021	RESISTOR CF 1/4W	32033-10030	100K	5%			
R2022	RESISTOR CF 1/4W	32033-10000	100	5%			12
R2023	RESISTOR CF 1/4W	32033-10000	100	5%			
R2024	RESISTOR CF 1/4W	32033-22020	22K	5%			7
R2025	RESISTOR CF 1/4W	32033-22020	22K	5%			
R2026	RESISTOR CF 1/4W	32033-22020	22K	5%			
R2027	RESISTOR CF 1/4W	32033-22020	22K	5%			
R2028	RESISTOR CF 1/4W	32033-56020	56K	5%			4
R2029	RESISTOR CF 1/4W	32033-56020	56K	5%			
R2030	RESISTOR CF 1/4W	32033-10030	100K	5%			
R2031	RESISTOR MF 1/4W	32035-26730	267K	1%		2673F	2
R2032	RESISTOR MF 1/4W	32035-20030	200K	1%		2003F	2
R2033	RESISTOR MF 1/4W	32035-26730	267K	1%		2673F	
R2034	RESISTOR MF 1/4W	32035-20030	200K	1%		2003F	
R2035	RESISTOR CF 1/4W	32033-10000	100	5%			
R2036	RESISTOR CF 1/4W	32033-10030	100K	5%			

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R2037	RESISTOR CF 1/4W	32033-56020	56K	5%			
R2038	RESISTOR CF 1/4W	32033-22020	22K	5%			
R2039	RESISTOR CF 1/4W	32033-33010	3K3	5%			1
R2040	RESISTOR CF 1/4W	32033-10000	100	5%			
R2041	RESISTOR CF 1/4W	32033-10030	100K	5%			
R2043	RESISTOR CF 1/4W	32033-10030	100K	5%			
R2044	RESISTOR CF 1/4W	32033-10030	100K	5%			
R2045	RESISTOR CF 1/4W	32033-62000	620	5%			
R2046	RESISTOR CF 1/4W	32033-10000	100	5%			
R2047	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	8
R2048	RESISTOR MF 1/4W	32035-43210	4K32	1%		4321F	
R2049	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R2050	RESISTOR MF 1/4W	32035-75010	7K5	1%		7501F	3
R2051	RESISTOR MF 1/4W	32035-68120	68K1	1%		6812F	1
R2052	RESISTOR CF 1/4W	32033-10000	100	5%			
R2053	RESISTOR CF 1/4W	32033-22010	2K2	5%			5
R2054	RESISTOR MF 1/4W	32035-24920	24K9	1%			1
R2055	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	9
R2056	RESISTOR MF 1/4W	32035-35710	3K57	1%		3571F	1
R2058	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R2059	RESISTOR MF 1/4W	320335-47510	4K75	1%		4751F	1
R2060	RESISTOR MF 1/4W	32035-14320	14K3	1%		1432F	1
R2061	RESISTOR MF 1/4W	32035-33210	3K32	1%		3321F	1
R2062	RESISTOR CF 1/4W	32033-27010	2K7	5%			2
R2063	RESISTOR CF 1/4W	32033-03300	33	5%			1
R2064	RESISTOR MF 1/4W	32035-04909	49R9	1%	CORN	49R9F	2
R2065	RESISTOR MF 1/4W	32035-04909	49R9	1%	CORN	49R9F	
R2067	RESISTOR MF 1/4W	32035-68110	6K81	1%		6811F	3
R2068	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R2069	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R2070	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R2071	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R2072	RESISTOR CF 1/4W	32033-22000	220	5%			7
R2073	RESISTOR CF 1/4W	32033-22000	220	5%			
R2074	RESISTOR CF 1/4W	32033-22000	220	5%			
R2075	RESISTOR MF 1/4W	32035-68110	6K81	1%		6811F	
R2076	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R2077	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R2078	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R2079	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R2080	RESISTOR CF 1/4W	32033-47010	4K7	5%			9
R2081	RESISTOR MF 1/4W	32035-28010	2K80	1%			3
R2082	RESISTOR MF 1/4W	32035-28010	2K80	1%			
R2083	RESISTOR CF 1/4W	32033-20010	2K0	5%			3
R2084	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R2085	RESISTOR MF 1/4W	32035-27420	27K4	1%		2742F	1
R2087	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R2088	RESISTOR MF 1/4W	32035-40220	40K2	1%			1

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R2089	RESISTOR MF 1/4W	32035-20020	20K0	1%		2002F	1
R2090	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R2091	RESISTOR CF 1/4W	32033-22010	2K2	5%			
R2092	RESISTOR CF 1/4W	32033-22010	2K2	5%			
R2093	RESISTOR MF 1/4W	32035-26110	2K61	1%			1
R2094	RESISTOR MF 1/4W	32035-28010	2K80	1%			
R2095	RESISTOR MF 1/4W	32035-68110	6K81	1%		6811F	
R2096	RESISTOR CF 1/4W	32033-10020	10K	5%			8
R2097	RESISTOR MF 1/4W	32035-39220	39K2	1%		3922F	1
R2098	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R2099	RESISTOR CF 1/4W	32033-06200	62	5%			1
R2100	RESISTOR CF 1/4W	32033-56030	560K	5%			2
R2101	RESISTOR MF 1/4W	32035-31610	3K16	1%		3161F	1
R2102	RESISTOR MF 1/4W	32035-57610	5K76	1%		5761	1
R2103	RESISTOR CF 1/4W	32033-10020	10K	5%			
R2104	RESISTOR CF 1/4W	32033-51010	5K1	5%			1
R2105	RESISTOR CF 1/4W	32033-68010	6K8	5%			1
R2106	RESISTOR CF 1/4W	32033-10000	100	5%			
R2107	RESISTOR CF 1/4W	32033-10020	10K	5%			
R2108	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R2109	RESISTOR CF 1/4W	32033-10000	100	5%			
R2110	RESISTOR CF 1/4W	32033-56010	5K6	5%			4
R2111	RESISTOR CF 1/4W	32033-56030	560K	5%			
R2112	RESISTOR CF 1/4W	32033-10020	10K	5%			
R2113	RESISTOR CF 1/4W	32033-10020	10K	5%			
R2114	RESISTOR CF 1/4W	32033-56010	5K6	5%			
R2115	RESISTOR CF 1/4W	32033-10020	10K	5%			
R2116	RESISTOR CF 1/4W	32033-22010	2K2	5%			
R2117	RESISTOR CF 1/4W	32033-10020	10K	5%			
R2118	RESISTOR CF 1/4W	32033-27010	2K7	5%			
R2119	RESISTOR CF 1/4W	32033-22010	2K2	5%			
R2120	RESISTOR CF 1/4W	32033-56010	5K6	5%			
R2121	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R2122	RESISTOR CF 1/4W	32033-56010	5K6	5%			
R2124	RESISTOR CF 1/4W	32033-10000	100	5%			
R2125	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R2126	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R2128	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R2129	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R2130	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R2131	RESISTOR CF 1/4W	32033-10030	100K	5%			
R2132	RESISTOR CF 1/4W	32033-47020	47K	5%			2
R2135	RESISTOR CF 1/4W	32033-33040	3M3	5%			2
R2137	RESISTOR CF 1/4W	32033-33040	3M3	5%			
R2139	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R2140	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R2141	RESISTOR CF 1/4W	32033-22020	22K	5%			
R2142	RESISTOR CF 1/4W	32033-47010	4K7	5%			

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R2143	RESISTOR CF 1/4W	32033-22020	22K	5%			
R2144	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R2145	RESISTOR CF 1/4W	32033-33000	330	5%			1
R2146	RESISTOR CF 1/4W	32033-10000	100	5%			
R2147	RESISTOR CF 1/4W	32033-10000	100	5%			
R2148	RESISTOR CF 1/4W	32033-56020	56K	5%			
R2149	RESISTOR CF 1/4W	32033-47020	47K	5%			
R2150	JUMPER						1
R2152	RESISTOR CF 1/4W	32033-10020	10K	5%			
R2153	RESISTOR MF 1/4W	32035-10010	1K00	1%		1001F	2
R2154	RESISTOR CF 1/4W	32033-10050	10M	5%			
R2155	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R2156	RESISTOR MF 1/4W	32035-24910	2K49	1%		2491F	2
R2157	RESISTOR MF 1/4W	32035-10010	1K00	1%		1001F	
R2158	RESISTOR MF 1/4W	32035-75010	7K5	1%		7501F	
R2159	RESISTOR MF 1/4W	32035-24910	2K49	1%		2491F	
R2160	RESISTOR MF 1/4W	32035-16520	16K5	1%		1652F	1
R2161	RESISTOR MF 1/4W	32035-43210	4K32	1%		4321F	2
R2162	RESISTOR MF 1/4W	32035-45300	453	1%		4530F	1
R2163	RESISTOR CF 1/4W	32033-22000	220	5%			
R2164	RESISTOR CF 1/4W	32033-22000	220	5%			
R2165	RESISTOR CF 1/4W	32033-22000	220	5%			
R2166	RESISTOR CF 1/4W	32033-22000	220	5%			
R2168	RESISTOR CF 1/4W	32033-62000	620	5%			2
R2169	RESISTOR CF 1/4W	32033-82010	8K2	5%			1
R2170	RESISTOR CF 1/4W	32033-15000	150	5%			1
R2171	RESISTOR CF 1/4W	32033-01000	10	5%			
R2172	RESISTOR MF 1/4W	32035-30100	301	1%		3010F	
R2173	RESISTOR MF 1/4W	32035-30100	301	1%		3010F	4
R2174	RESISTOR CF 1/4W	32033-01000	10	5%			
R2175	RESISTOR MF 1/4W	32035-30100	301	1%		3010F	
R2176	RESISTOR MF 1/4W	32035-40200	402	1%		4020F	2
R2177	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	14
R2178	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	12
R2179	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2180	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2181	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2182	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2183	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2184	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2185	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2186	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2187	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2188	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2189	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2190	RESISTOR MF 1/4W	32035-66500	665	1%		6650F	2
R2191	RESISTOR MF 1/4W	32035-93100	931	1%		9310F	2
R2192	RESISTOR NOT USED						

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R2193	RESISTOR CF 1/4W	32033-01000	10	5%			4
R2194	RESISTOR CF 1/4W	32033-01000	10	5%			
R2195	RESISTOR CF 1/4W	32033-02200	22	5%			4
R2196	RESISTOR CF 1/4W	32033-02200	22	5%			
R2197	RESISTOR CF 1/4W	32033-02200	22	5%			
R2198	RESISTOR CF 1/4W	32033-02200	22	5%			
R2199	RESISTOR MF 1/4W	32035-30100	301	1%		3010F	
R2200	RESISTOR MF 1/4W	32035-40200	402	1%		4020F	
R2201	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2202	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2203	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2204	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2205	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2206	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2207	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2208	RESISTOR MF 1/4W	32035-59000	590	1%		5990F	
R2209	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2210	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2211	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2212	RESISTOR MF 1/4W	32035-59000	590	1%		5900F	
R2213	RESISTOR MF 1/4W	32035-86600	866	1%		8660F	
R2214	RESISTOR MF 1/4W	32035-66500	665	1%		6650F	
R2215	RESISTOR MF 1/4W	32035-93100	931	1%		9310F	
R2216	RESISTOR CF 1/4W	32033-22040	2M2	5%			
R2217	RESISTOR CF 1/4W	32033-10000	100	5%			
R2218	RESISTOR CF 1/4W	32022-20010	2K0	5%			2
R2219	RESISTOR CF 1/4W	32022-20010	2K0	5%			
R2220	RESISTOR MF 1/4W	32035-64900	649	1%		6490F	1
R2221	RESISTOR MF 1/4W	32035-75010	7K5	1%		7501F	1
S2001	PUSHBUTTON SWITCH				SCHW	F10GR6U	3
S2002	PUSHBUTTON SWITCH				SCHW	F10GR6U	
S2003	PUSHBUTTON SWITCH				SCHW	F10GR6U	
S2004	PUSHBUTTON SWITCH				SCHW	F10GR2U	
U2001	SEMICON OP AMP BI-FET DUAL	25111-07200				TL-072CP	1
U2002	SEMICON OP AMP PRECISION	25311-31800				LM318	1
U2003	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	13
U2004	SEMICON LINEAR DUAL OTA	25430-32800				CA3280	2
U2005	SEMICON OP AMP BI-FET DUAL	25111-06200				TL-062CP	2
U2006	SEMICON OP AMP FET	25411-41100				LF411CN	3
U2007	SEMICON OP AMP FET	25411-41100				LF411CN	
U2008	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2009	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2010	SEMICON TRANSISTOR ARRAY SEL	23316-68420			MOT	MPQ6842	1
U2011	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2012	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2013	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2014	SEMICON CMOS SWITCH	24021-40530				CD4053B	2
U2015	SEMICON CMOS SWITCH	24021-40530				CD4053B	

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
U2016	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2017	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2018	SEMICON OP AMP BI-FET DUAL	25111-06200				TL-062CP	
U2019	SEMICON OP AMP J FET	25311-35600				LF356N	1
U2020	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2021	SEMICON LINEAR DUAL OTA	25430-32800				CA3280	
U2022	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2023	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2024	SEMICON BI-FET OP AMP	25111-07100				TL-071CP	1
U2025	SEMICON TRANSISTOR ARRAY	23316-68420			MOT	MPQ6842	2
U2026	SEMICON LINEAR NEG REG 15B	25992-79150	15V			7915	1
U2027	SEMICON POS REG 15V	25992-78150	15V			7815	1
U2028	SEMICON OP AMP FET	25411-41100				LF411CN	
U2029	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2030	SEMICON OP AMP LO NOISE LIN	25511-55340				NE5534AN	
U2031	SEMICON TRANSISTOR ARRAY	23316-68420			MOT	MPQ6842	
V2001	RESISTOR TRIM CONTROL ST	51415-50020	50K			3386P-1-503	
V2002	RESISTOR TRIM CONTROL ST	51415-50020	50K			3386P-1-503	
V2003	RESISTOR TRIM CONTROL ST	51415-10010	1K			3386P-1-102	2
V2004	RESISTOR TRIM CONTROL ST	51415-10000	100			3386P-1-101	1
V2005	RESISTOR TRIM CONTROL ST	51415-50020	50K			3386P-1-503	8
V2006	RESISTOR TRIM CONTROL ST	51415-10020	10K			3386P-1-103	2
V2007	RESISTOR TRIM CONTROL ST	514115-50020	50K			3386P-1-503	
V2008	RESISTOR TRIM CONTROL ST	51415-50020	50K			3386P-1-503	
V2009	RESISTOR TRIM CONTROL ST	51415-50020	50K			3386P-1-503	
V2010	RESISTOR TRIM CONTROL ST	51415-50020	50K			3386P-1-503	
V2011	RESISTOR TRIM CONTROL ST	51415-50020	50K			3386P-1-503	
V2012	RESISTOR TRIM CONTROL ST	51415-10020	10K			3386P-1-103	
V2013	RESISTOR TRIM CONTROL ST	51415-10010	1K			3386P-1-102	
V2014	RESISTOR MF 1/4W	32035-49900	499	1%		4990F	1
V2015	QUAD COND PLASTIC POT		20K				1
V2017	TRIM POT SINGLE TURN		2K				1
V2106	CONDUCTIVE PLASTIC POT	51116-05001	5K			U-5K-B2	1

LINEAR REGULATOR & BATTERY CHARGER

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	VOLTAGE REGULATOR 5V 1A					UA7805UC	1
	SEMICON TRANSISTOR NPN DAR	22522-12201			TI	TIP122	2
	SEMICON TRANSISTOR NPN DAR	22522-12201			TI	TIP122	
	PRINTED CIRCUIT BOARD	13501-44002				3501-440-03	1
	CONNECTOR HOUSING 14PIN	78014-21510				22-01-2141	1
	CONNECTOR SOCKET PCB DIL 14PIN	71014-21439				214-AG39D	3
	CONNECTOR SOCKET PCB DIL 14PIN	71014-21439				214-AG39D	
	CONNECTOR SOCKET PCB DIL 14PIN	71014-21439				214-AG39D	
C401	CAPACITOR ALUM ELE 25V	48030-22010	2200	20%		82009/2200/25V	1
C402	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	10
C403	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C404	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C405	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C406	CAPACITOR PLASTIC FILM	45042-22030	0.22	5%		MKS2 0.22/63/5W	2
C407	CAPACITOR PLASTIC FILM	45042-15020	0.015	20%		MKS3 0.015/100/5W	3
C408	CAPACITOR PLASTIC FILM	45042-10030	0.1	5%		MKS3 0.1/100/20W	1
C409	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C410	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C412	CAPACITOR PLASTIC FILM	45042-15020	0.015	20%		MKS3 0.015/100/5W	
C413	CAPACITOR ALUM ELE 22/25	48030-02200	22	20%			1
C414	CAPACITOR PLASTIC FILM	45042-15020	0.015	20%		MKS3 0.015/100//5W	
C415	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			1
C416	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%			2
C417	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C418	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C419	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C420	CAPACITOR ALUM ELE 10/40	48050-01000	10	20%		85200/10/40V	1
C421	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C422	CAPACITOR TANTALUM 10/25V	47031-01000	10	20%			
C423	CAPACITOR PLASTIC FILM	45042-22030	0.22	5%	WIMA	MKS2 0.22/63/5W	
D401	SEMICON RECTIFIER	21107-54040				1N5404	6
D402	SEMICON RECTIFIER	21107-54040				1N5404	
D403	SEMICON RECTIFIER	21107-54040				1N5404	
D404	SEMICON RECTIFIER	21107-54040				1N5404	
D405	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	8
D406	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D407	SEMICON RECTIFIER	21107-54040				1N5404	
D408	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D409	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D410	SEMICON DIODE ZENER 1W	21135-47440				1N4744	2
D411	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D412	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D413	SEMICON RECTIFIER	21107-54040				1N5404	
D414	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D415	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
D417	SEMICON DIODE ZENER 1W	21135-47440	15V			1N4744	
F400	FUSE 3 AMP	85313-03000	3A		LTLF	313003	1
F401	NOT USED						
J401	CONNECTOR FLAT CABLE 16PIN	72016-16780			ANSL	609-1678	1
J402	CONNECTOR HEADER LATCH 4PIN	78003-20410			MLX	22-29-2041	4
J403	CONNECTOR HEADER LATCH 4PIN	78003-20410			MLX	22-29-2041	
J404	CONNECTOR HEADER LATCH 4PIN	78003-20410			MLX	22-29-2041	
J405	CONNECTOR HEADER LATCH 4PIN	78003-20410			MLX	22-29-2041	
Q401	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	1
Q402	SEMICON SHUNT REGULATOR	25992-43100			TI	TL431CLP	1
Q403	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	1
R401	RESISTOR CF 1/2W	32033-12010	1K2	5%			2
R402	RESISTOR WW 3W		0.22	5%			1
R403	RESISTOR CF 1/4W	32033-15010	1K5	5%			3
R404	RESISTOR CF 1/4W	32033-39010	3K9	5%			1
R405	RESISTOR CF 1/4W	32033-68000	680	5%			1
R406	RESISTOR CF 1/4W	32033-12010	1K2	5%			
R407	RESISTOR CF 1/4W	32033-15030	150K	5%			2
R408	RESISTOR CF 1/4W	32033-04700	47	5%			1
R409	RESISTOR CF 1/4W	32033-10020	10K	5%			8
R410	RESISTOR CF 1/4W	32033-12020	12K	5%			1
R411	RESISTOR CF 1/4W	32033-15010	1K5	5%			
R412	RESISTOR CF 1/4W	32033-10020	10K	5%			
R414	RESISTOR CF 1/4W	32033-15010	1K5	5%			
R415	RESISTOR CF 1/4W	32033-10020	10K	5%			
R416	RESISTOR CF 1/4W	32033-47010	4K7	5%			5
R417	RESISTOR CF 1/4W	32033-27000	270	5%			2
R418	RESISTOR CF 1/4W	32033-10030	100K	5%			3
R419	RESISTOR CF 1/4W	32033-10040	1M0	5%			5
R420	RESISTOR CF 1/4W	32033-15030	150K	5%			
R421	RESISTOR CF 1/4W	32033-82020	82K	5%			1
R422	RESISTOR CF 1/4W	32033-10030	100K	5%			
R423	RESISTOR CF 1/4W	32033-10040	1M0	5%			
R424	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R425	RESISTOR CF 1/4W	32033-47040	4M7	5%			1
R426	RESISTOR CF 1/4W	32033-10010	1K0	5%			3
R427	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R428	RESISTOR CF 1/4W	32033-27000	270	5%			
R429	RESISTOR CF 1/4W	32033-10010	1K0	5%			
R430	RESISTOR CF 1/4W	32033-10040	1M0	5%			
R431	RESISTOR CF 1/4W	32033-10030	100K	5%			
R432	RESISTOR CF 1/4W	32033-47030	470K	5%			2
R433	RESISTOR CF 1/4W	32033-10020	10K	5%			
R434	RESISTOR CF 1/4W	32033-10020	10K	5%			
R435	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	3
R436	RESISTOR MF 1/4W	32035-11520	11K5	1%		1152F	1
R437	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R438	RESISTOR CF 1/4W	32033-27010	2K7	5%			3

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USE
R439	RESISTOR CF 1/4W	32033-27010	2K7	5%			
R440	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R441	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R442	RESISTOR CF 1/4W	32033-15020	15K	5%			
R444	RESISTOR CF 1/4W	32033-10020	10K	5%			
R445	RESISTOR CF 1/4W	32033-27010	2K7	5%			
R446	RESISTOR CF 1/4W	32033-10040	1M0	5%			
R447	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R448	RESISTOR CF 1/4W	32033-22010	2K2	5%			1
R449	RESISTOR CF 1/4W	32033-47030	470K	5%			
R450	RESISTOR CF 1/2W	32033-12010	1K2	5%			
R451	RESISTOR CF 1/4W	32033-10040	1M0	5%			
R452	RESISTOR CF 1/4W	32033-10020	10K	5%			
R453	RESISTOR CF 1/4W	32033-10020	10K	5%			
R454	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R455	RESISTOR NOT USED						
U401	SEMICON QUAD OP AMP	25321-32400			NTL	LM324N	
U402	SEMICON QUAD OP AMP	25321-32400			NTL	LM324N	
U403	QUAD NORGATE CMOS					MC14001BCP	1
VR401	RESISTOR TRIM CONTROL ST	51415-10020	10K	10%	BRNS	3386P-1-103	2
VR403	TRIMMER SINGLE TURN		10K	10%		3386P-1-103	

SWITCHING POWER SUPPLY

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	FEEDTHRU CAPS					2402-000-X5U0-102P	8
	FERRITE BEADS					56-59065-4A6	8
	PRINTED CIRCUIT BOARD	13501-45002				3501-450-03	1
C500	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	12
C501	CAPACITOR TANTALUM 1.5/25V	47031-01590	1.5	20%			1
C502	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C503	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C504	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C505	CAPACITOR TANTALUM 10/25V	47031-01000	10.0	20%			
C506	NOT USED						
C507	CAPACITOR CERAMIC DISC 50V	41033-10030	0.01	20%			2
C508	CAPACITOR TANTALUM 10/25V	47031-01000	10.0	20%			2
C509	NOT USED						
C510	CAPACITOR CERAMIC DISC	41933-03000	30P	20%		DD300	1
C511	CAPACITOR CERAMIC DISC	41033-04700	47P	20%		GH470K	1
C512	NOT USED						
C513	NOT USED						
C514	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%	SIEM	B37988J5104M	
C515	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%	SIEM	B37988J5104M	
C516	CAPACITOR ELECT 10/40	48050-01000	10.0	20%	SIEM	85200 10UF 40V	4
C517	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%	SIEM	B37988J5104M	
C518	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%	SIEM	B37988J5104M	
C519	CAPACITOR ELECT 10/40	48050-01000	10.0	20%	SIEM	85200 10UF 40V	
C520	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C521	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C522	CAPACITOR ELECT 10/40	48050-01000	10.0	20%	SIEM	85200 10UF 40V	
C523	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C524	CAP MONOLYTIC CERAMIC	42031-10030	0.1	20%		B37988J5104M	
C525	CAPACITOR ELECT 10/40	48050-01000	10.0	20%	SIEM	85200 10UF 40V	
C526	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C527	CAPACITOR FILM	45042-22030	.22	5%		MKS2 0.22/63/5W	1
D501	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	10
D502	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D503	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D504	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D505	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D506	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D507	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D508	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D509	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D510	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D511	NOT USED						
D512	NOT USED						
L501	INDUCTOR 270MA	53102-15374	15MH			1537-40	7
L502	INDUCTOR CHOKE	53102-15320				1532A	1

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
L503	INDUCTOR 270MA	53102-15374	15MH			1537-40	
L504	INDUCTOR 270MA	53102-15374	15MH			1537-40	
L505	INDUCTOR 270MA	53102-15374	15MH			1537-40	
L506	INDUCTOR 270MA	53102-15374	15MH			1537-40	
L507	INDUCTOR 270MA	53102-15374	15MH			1537-40	
L508	INDUCTOR 270MA	53102-15374	15MH			1537-40	
N501	RESISTOR NET 8 PIN 4 RES SIP	39735-10030	100K	5%		804-104G	1
Q501	VMOS FET		1A40V			VN10KM	2
Q502	VMOS FET		1A40V			VN10KM	
Q503	SEMICON FET VMOS POWER N CH	22722-52010	8A40V			IVN5201CND	2
Q504	SEMICON FET VMOS POWER N CH	22722-52010	8A40V			IVN5201CND	
R501	RESISTOR CF 1/4W	32033-27000	270	5%			2
R502	RESISTOR CF 1/4W	32033-27000	270	5%			
R503	RESISTOR CF 1/4W	32033-10020	10K	5%			1
R504	RESISTOR CF 1/4W	32033-10040	1M0	5%			1
R505	RESISTOR CF 1/4W	32033-33010	3K3	5%			1
R506	RESISTOR CF 1/4W	32033-01000	10	5%			2
R507	RESISTOR CF 1/4W	32033-01000	10	5%			
T500	TRANSFORMER HI FREQUENCY	53511-23753			AMB	2375	1
U501	DUAL JK FF CMOS					MC14027BCP	1
U502	HEX INV CMOS					MC14049UBCP	1

FRONT PANEL

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	PRINTED CIRCUIT BOARD				AMBR	3501-480-03	1
D801	SEMICON LED RECT YELLOW	21545-53124			GI	MV53124	1
D802	SEMICON LED RECT GREEN	21555-52124			GI	MV52124	1
D803	SEMICON LED RECT RED	21525-57124			GI	MV57124	1
J801	CONNECTOR HEADER LATCH 4PIN	78003-20410			MOLX	22-29-2041	6
J802	CONNECTOR HEADER LATCH 4PIN	78003-20410			MOLX	22-29-2041	
J803	CONNECTOR HEADER LATCH 4PIN	78003-20410			MOLX	22-29-2041	
J804	CONNECTOR HEADER LATCH 4PIN	78003-20410			MOLX	22-29-2041	
J805	CONNECTOR FLAT CABLE 16PIN	72016-16780			AUGT	609-1678	1
J806	CONNECTOR HEADER LATCH 4PIN	78003-20410			MOLX	22-29-2041	
J809	CONNECTOR HEADER LATCH 4PIN	78003-20410			MOLX	22-29-2041	
P801	CONNECTOR SOCKET R-T-S PCB	74003-38800			ADC	PC388J	1
P807	NOT USED						
P808	NOT USED						
P810	NOT USED						
R801	RESISTOR MF 1W	32035-30100	301	1%		3010F	1
R802	RESISTOR MF 1W	34065-60000	600	1%	CNSA	RN70D	1
R803	RESISTOR MF 1/4W	32035-16520	16K5	1%		1652F	1
R804	RESISTOR CF 1/4W	32033-86000	860	5%			1
R805	RESISTOR CF 1/4W	32033-13030	130K	5%			1
R806	RESISTOR MF 1/4W	32035-75010	7K5	1%		7501F	1
S801	SWITCH PUSHBUTTON 2U	84211-01001			SCHW	F2UEE	4
S802	SWITCH PUSHBUTTON 2U	84211-01001			SCHW	F2UEE	
S803	SWITCH PUSHBUTTON 6PDT	82620-06000			SCHW	F6UEE	1
S804	SWITCH PUSHBUTTON 2U	84211-01001			SCHW	F2UEE	
S805	SWITCH PUSHBUTTON 2U	84211-01001			SCHW	F2UEE	
V801	SWITCH ASSEMBLY POT SPDT	51196-38825	25K		AB	VS388-25K	1

OPTION : PRE AMP

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	PCB CONNECTOR				MOLX	22-17-2042	4
	FUSE CLIPS	67620-10206			LTLF	102068	2
	PRINTED CIRCUIT BOARD	13501-43002			AMBR	3501-430-03	1
C301	CAPACITOR CERAMIC DISC	41033-04700	47P	20%		GH470K	1
C302	CAPACITOR CERAMIC DISC	41033-03000	30P	20%		DD300	1
C303	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			5
C304	CAPACITOR CERAMIC DISC	41033-01000	10P	20%	0	GG100K	2
C305	CAPACITOR ALUM ELE 10/40	48050-01000	10	20%		85200/10/40V	2
C306	TRIM CAP 7-25P		25P		ERIE	538-011B7-25	1
C307	CAPACITOR CERAMIC DISC	41033-33000	330P	20%			1
C308	CAPACITOR CERAMIC DISC	41033-01000	10P	20%		GG100K	
C309	CAPACITOR ALUM ELE 10/40	48050-01000	10	20%		85200/10/40V	
C310	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C311	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C312	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C313	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C314	CAPACITOR NOT USED						
C315	CAPACITOR NOT USED						
C316	CAPACITOR NOT USED						
D301	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	7
D302	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D303	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D304	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D305	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D306	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	2
D307	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
D308	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D309	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
F301	FUSE 3AG FAST	85312-06210	63MA		LTLF	312062	1
Q301	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	7
Q302	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q303	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q304	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q305	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q306	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q307	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	5
Q308	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q309	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q310	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
Q311	SEMICON TRANSISTOR PNP GP	22192-44030				2N4403	
Q312	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	
R301	RESISTOR MF 1/4W	32035-32400	324	0.1%			1
R302	RESISTOR CF 1/4W	32033-10020	10K	5%			4
R303	RESISTOR CF 1/4W	32033-22020	22K	5%			3
R304	RESISTOR CF 1/4W	32033-20000	200	5%			3

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R305	RESISTOR MF 1/4W	32035-11010	1K1	0.1%			1
R306	RESISTOR CF 1/4W	32033-22020	22K	5%			
R307	RESISTOR CF 1/4W	32033-10020	10K	5%			
R308	RESISTOR CF 1/4W	32033-20000	200	5%			
R309	RESISTOR MF 1/4W	32035-46410	4K64	0.1%			1
R310	RESISTOR CF 1/4W	32033-22020	22K	5%			
R311	RESISTOR CF 1/4W	32033-10020	10K	5%			
R312	RESISTOR CF 1/4W	32033-20000	200	5%			
R313	RESISTOR CF 1/4W	32033-47000	470	5%			3
R314	RESISTOR CF 1/4W	32033-47090	47	5%			1
R315	NOT USED						
R316	RESISTOR MF 1/4W	32035-49910	4K99	0.1%			1
R317	RESISTOR CF 1/4W	32033-10020	10K	5%			
R318	RESISTOR CF 1/4W	32033-13000	130	5%			1
R319	RESISTOR CF 1/4W	32033-47000	470	5%			
R320	RESISTOR MF 1/4W	32035-24910	2K49	0.1%			1
R321	RESISTOR MF 1/4W	32035-56200	562	0.1%			1
R322	RESISTOR MF 1/4W	32035-24910	2K49	1%		2491F	1
R323	RESISTOR MF 1/4W	32035-47510	4K75	1%			1
R325	RESISTOR CF 1/4W	32033-36000	360	5%			1
R326	RESISTOR CF 1/4W	32033-33000	330	5%			2
R327	RESISTOR CF 1/4W	32033-62090	62	5%			2
R328	RESISTOR CF 1/4W	32033-62090	62	5%			
R329	RESISTOR CF 1/4W	32033-33000	330	5%			
R330	RESISTOR CF 1/4W	32033-47010	4K7	5%			3
R331	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R332	RESISTOR CF 1/4W	32033-47010	4K7	5%			
R333	RESISTOR CF 1/4W	32033-47000	470	5%			
U301	RELAY REED 1A	89100-92512	12V		CLAR	925A12C1A	3
U302	RELAY REED 1A	89100-92512	12V		CLAR	925A12C1A	
U303	RELAY REED 1A	89100-92512	12V		CLAR	925A12C1A	
U304	SEMICON DUAL N CH FET	22318-25146			TOS	2SK146GR	1
U305	SEMICON OP AMP LO NOISE LIN	25511-55340			SIG	NE5534AN	1
V300	RESISTOR TRIM CONTROL ST	51415-50000	500		BRNS	3386P-1-501	1

OPTION : IMD

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
	PRINTED CIRCUIT BOARD	13501-46002				3501-460-03	1
	CONNECTOR 4 PIN HEADER	73104-20410	6410			22-29-2041	3
	SOCKET DIL 16 PIN	71016-21639				216-AG39D	6
	SOCKET DIL 8 PIN	71008-20839				208-AG39D	1
C601	CAPACITOR PLASTIC FILM	45049-22030	0.22	20%		MKS2/0.22	3
C602	CAPACITOR PLASTIC FILM	45049-22030	0.22	20%		MKS2/0.22	
C603	CAPACITOR PLASTIC FILM	45042-47020	0.047	10%		MKS3/0.047	1
C604	CAPACITOR PLASTIC FILM	45049-22030	0.22	20%		MKS2/0.22	
C605	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	4
C606	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C607	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			
C608	CAPACITOR CERAMIC DISC	41033-10030	0.01	20%			2
C609	CAPACITOR TANTALUM 25V	47121-10050	10	20%			2
C610	CAPACITOR TANTALUM 25V	47121-10050	10	20%			
C611	CAPACITOR ALUM ELE AXIL 100/25	48030-10000	100	20%		81009/100/25V	2
C612	CAPACITOR ALUM ELE AXIL 100/25	48030-10000	100	20%		81009/100/25V	
C613	CAPACITOR CERAMIC DISC	41031-10090	10P	20%		GG100K	
C621	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	9
C622	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	
C623	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	
C624	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	
C625	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	
C626	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	
C627	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	
C628	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	
C629	CAPACITOR CERAMIC DISC	41031-10090	10P	20%		GG100K	2
C630	CAPACITOR CERAMIC DISC	41031-30090	30P	20%			1
C631	CAPACITOR PLASTIC FILM	45043-15020	0.015	5%		MKS3/0.015	4
C632	CAPACITOR PLASTIC FILM	45043-15020	0.015	5%		MKS3/0.015	
C633	CAPACITOR PLASTIC FILM	45043-15020	0.015	5%		MKS3/0.015	
C634	CAPACITOR PLASTIC FILM	45043-15020	0.015	5%		MKS3/0.015	
C635	CAPACITOR PLASTIC FILM	45042-22020	0.022	10%		MKS3/0.022	1
C636	CAPACITOR PLASTIC FILM	45043-10020	0.01	5%		MKS3/0.01	
C637	CAPACITOR PLASTIC FILM	45043-68010	6800P	5%		FKC3/6800	1
C638	CAPACITOR PLASTIC FILM	45063-33020	0.033	5%		MKS3/0.033	1
C639	CAPACITOR PLASTIC FILM	45043-22010	2200P	5%		FKC3/2200	2
C640	CAPACITOR PLASTIC FILM	45042-10030	0.1	20%		MKS3 0.1/100/20W	
C641	CAPACITOR PLASTIC FILM	45042-10030	0.1	20%		MKS3 0.1/100/20W	
C642	CAPACITOR PLASTIC FILM	45042-10030	0.1	20%		MKS3 0.1/100/20W	3
C644	CAPACITOR ALUM ELE RAD 10/40	48050-01000	10	20%		85200/10/40V	
C645	NOT USED						
C646	CAPACITOR ALUM ELE RAD 10/40	47121-10050	10	20%			
C647	NOT USED						
C648	CAPACITOR PLASTIC FILM	45043-22010	2200P	5%		FKC3/2200	
C649	CAPACITOR PLASTIC FILM	45043-10010	1000P	5%		FKC3/1000	1

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
C650	CAPACITOR PLASTIC FILM	45043-22000	220P	5%		FKC3/220	1
D601	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	16
D602	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D603	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D604	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D605	SEMICON DIODE GEN PUROSE	21135-41500				1N4150	
D606	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D607	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D608	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D609	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D610	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D611	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D612	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D613	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D614	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D615	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
D616	SEMICON DIODE GEN PURPOSE	21135-41500				1N4150	
J602	CONNECTOR FLAT CABLE 16PIN	72016-16780				609-1678	1
Q601	SEMICON FET N CHANNEL	22318-48610				2N4861	1
Q602	SEMICON TRANSISTOR NPN GP	22292-44010				2N4401	1
Q603	SEMICON SHUNT REGULATOR	25992-43100				TL431CLP	1
R601	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	14
R602	RESISTOR MF 1/4W	32035-82520	82K5	1%		8252F	1
R603	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R604	RESISTOR MF 1/4W	32035-12120	12K1	1%		1212F	3
R605	RESISTOR MF 1/4W	32035-12120	12K1	1%		1212F	
R606	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R607	RESISTOR MF 1/4W	32035-47500	475	1%		4750F	3
R608	RESISTOR CF 1/4W	32033-10030	100K	5%			3
R609	RESISTOR CF 1/4W	32033-10030	100K	5%			
R610	RESISTOR CF 1/4W	32033-10030	100K	5%			
R611	RESISTOR CF 1/4W	32033-33030	330K	5%			1
R612	RESISTOR MF 1/4W	32035-33230	332K	1%		3323F	1
R613	RESISTOR MF 1/4W	32035-33230	432K	1%			1
R614	RESISTOR MF 1/4W	32035-40220	40K2	1%		4022F	2
R615	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R616	RESISTOR MF 1/4W	32035-47500	475	1%		4750F	
R617	RESISTOR MF 1/4W	32035-47500	475	1%		4750F	
R618	RESISTOR CF 1/4W	32035-10020	10K	5%			8
R619	RESISTOR CF 1/4W	32035-10020	10K	5%			
R620	RESISTOR CF 1/4W	32035-10020	10K	5%			
R621	RESISTOR MF 1/4W	32035-78710	7K87	1%		7871F	1
R622	RESISTOR MF 1/4W	32035-80610	8K06	1%		8060F	1
R623	RESISTOR MF 1/4W	32035-66510	6K65	1%		6651F	1
R624	RESISTOR MF 1/4W	32035-95310	9K53	1%		9531F	1
R625	RESISTOR MF 1/4W	32035-44210	4K42	1%		4421F	1
R626	RESISTOR MF 1/4W	32035-14320	14K3	1%		1432F	1
R627	RESISTOR MF 1/4W	32035-15410	1K54	1%		1541F	1

DESIG	DESCRIPTION	AMBER PART NUMBER	ELECT VALUE	TOL	MFG	MANUFACTURER PARTS NUMBER	QTY USED
R628	RESISTOR MF 1/4W	32035-40220	40K2	1%		4022F	
R629	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	2
R630	RESISTOR MF 1/4W	32035-51120	51K1	1%		5112F	1
R631	RESISTOR CF 1/4W	32033-10050	10M	5%			1
R632	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R633	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R634	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R635	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R636	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R637	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R638	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R639	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R640	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R641	RESISTOR MF 1/4W	32035-10020	10K0	1%		1002F	
R642	RESISTOR CF 1/4W	32033-10020	10K	5%			
R643	RESISTOR CF 1/4W	32033-10000	100	5%			5
R644	RESISTOR MF 1/4W	32035-12120	12K1	1%		1212F	
R645	RESISTOR MF 1/4W	32035-20020	20K0	1%		2002F	1
R646	RESISTOR CF 1/4W	32033-10020	10K	5%			
R647	RESISTOR CF 1/4W	32033-10020	10K	5%			
R648	RESISTOR CF 1/4W	32033-10020	10K	5%			
R649	JUMPER						
R650	RESISTOR MF 1/4W	32035-80600	806	1%		8060F	1
R651	RESISTOR CF 1/4W	32033-10000	100	5%			
R652	RESISTOR CF 1/4W	32033-10020	10K	5%			
R653	RESISTOR MF 1/4W	32035-64900	649	1%		6490F	1
R654	RESISTOR CF 1/4W	32033-10000	100	5%			
R655	RESISTOR CF 1/4W	32033-10000	100	5%			
R656	RESISTOR MF 1/4W	32035-49910	4K99	1%		4991F	
R657	RESISTOR CF 1/4W	32033-10000	100	5%			
RL601	RELAY REED 2A		12V			925A12C2A	2
RL602	RELAY REED 2A		12V			925A12C2A	
U600	SEMICON OP AMP BI-FET DUAL	25111-06200				TL-062CP	
U601	SEMICON OP AMP BI-FET DUAL	25111-06200				TL-062CP	4
U602	SEMICON OP AMP BI-FET DUAL	25111-07200				TL-072CP	
U603	SEMICON OP AMP BI-FET DUAL	25111-06200				TL-062CP	
U604	SEMICON OP AMP BI-FET DUAL	25111-06200				TL-062CP	
U605	SEMICON OP AMP BI-FET DUAL	25111-07200				TL-072CP	5
U606	SEMICON OP AMP BI-FET DUAL	25111-07200				TL-072CP	
U607	RESISTOR NETWORK	38434-22020	22K	2%		4116R001223	1
U608	SEMICON OP AMP BI-FET DUAL	25111-07200				TL-072CP	
U609	SEMICON OP AMP BI-FET DUAL	25111-07200				TL-072CP	
U610	SEMICON CMOS SWITCH	24021-40530				CD4053B	1
V601	RESISTOR TRIM CONTROL ST	51415-10020	10K	10%		3386P-1-103	1

MP MASTER
MA23856